Unitil

Fitchburg Gas and
Electric Light Company

Sawyer Passway Distribution Study

Kevin E. Sprague
Unitil Service Corp.
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Sawyer Passway Electric Distribution Study
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1 EXECUTIVE SUMMARY

This study is limited in scope to those distribution projects which need to be completed in order to facilitate building the Sawyer Passway Substation. The goal of this study is to determine the final configuration required at the new substation. This study does not detail how to get from the substation to existing circuit/feeder locations. That will be determined during the design process.

This study will demonstrate that through circuit transfers and the use of stepdown transformers, the 4kV circuits originating out of Electric Station can be served in other ways. Therefore, the new substation will not require any 4kV transformation. This will greatly reduce the cost associated with the new substation by eliminating the need for 4kV transformation at Sawyer Passway.

If 4kV transformation were to remain at Sawyer Passway, the 13.8kV transformation will need to be increased as well. This leads to paying for double transformation which is not required. The added 13.8kV transformation required would in turn place a higher load requirement on Summer Street as a backup. This would further limit the transformation available at Summer Street for load growth or circuit transfers. This project also falls in line with the future goal of spreading 13.8kV throughout the system.

Throughout this report, the terms Electric Station and Sawyer Passway will be used quite frequently. Electric Station is used to identify the existing substation and Sawyer Passway is used to identify the new substation.

2 INTRODUCTION

Electric Station was once the center of the FG&E electric production. Over the years, all of the generators have been removed from the site which left FG&E with an old substation located in an old building.

Most of the equipment inside the building is old and very difficult to maintain due to the unavailability of spare parts. It has also been determined that the equipment which is 30-50 years old has no value to be reused in the new substation. The only pieces of equipment which might have some value are the 13.8-4kV transformer and some relatively newer reactors. These should be removed from the building and saved as spares. It is recommended to remove all of the equipment under a 2001 budget item.

Besides the age of the equipment, the building itself is in poor condition. The new substation will allow all of the equipment from the building to be removed and decommissioned. The final disposition for the building has not yet been determined.

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The study developed by Parsons Power Group Inc. (Exhibit A) concluded that the best spot for the new substation is the Sawyer Passway site. Their reasons for this are as follows:

1) Maximizes the use of the existing 69kV transmission facilities
2) Maximizes the use of the existing 13.8 and 4kV distribution getaways
3) Good, clean, level site
4) Most cost effective
5) Provides ready source of power for future site development
6) Facilitates the ultimate elimination of Wallace Rd. and Nockege substations
7) Takes advantage of existing ties between Beech St. and Summer St. substations

The purpose of this report is to detail a precise short term, cost-effective plan for the distribution system which originates from Electric Station. This report has taken into consideration concepts such as O&M costs, age/condition of plant, and room for growth and expansion. The goals of this study are as follows:

A) Determine how all area distribution loads will be served upon completion of the new substation.
B) Determine all parameters necessary to complete the substation design.
C) Eliminate radial load from the #8 network feeder.
D) Develop year 2000 capital budget items including project scope, justification, and costs.
E) Develop five year capital budget items including project scope, justification, and costs.

3 ELECTRIC STATION DESCRIPTION

Electric Station is normally served in a looped configuration with the 06 Line, 3A and 9 feeders in parallel. The existing configuration has a 69-13.8kV Wye-Delta transformer feeding the 13.8kV bus. The 3A and 9 feeders originating from Summer Street are the backup supply to the 13.8kV bus. These positions will be maintained in the Sawyer Passway substation design.

Other than the 3A and 9 feeder positions, all the network feeders originate from this bus (8, 10, 10A, 10B, and 11). The #7 feeder is a normally open tie between Electric Station and Beech St. substation. This cable is old and has not been used for a long time. This cable was tested in 1999 and determined to be unusable. The #17 feeder runs in parallel with the #10 feeder with an automatic bus transfer at Nockege substation. The drawing which best displays this configuration is the System Oneline Diagram Simplified (FCYTD001). This is shown in Exhibit B.

Also located on the 13.8kV bus at Electric Station is a 13.8-4kV Delta-Wye transformer. This transformer serves the 4kV bus which has five circuits originating from it (1, 2, 4, 9, and 13). These circuits serve customers in the area immediately surrounding Main Street. For a substation oneline, see Exhibit C.

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All of the 4kV circuits exit from Electric Station by the use of underground cable in ducts. The cable is a combination of varnished cambric cable and PILC (Paper Insulated Lead Cable). The paper insulation of the PILC cable is impregnated with oil. This oil serves two functions: 1) increases dielectric strength of the cable and 2) keeps water from penetrating into the cable. All of these cables are extremely old and most if not all of the oil has dried up. These are major contributing factors to most of the troubles on these circuits. Due to this fact, if the PILC cable could be removed from normal operation, the reliability of these circuits should greatly increase.

By the end of 1999, circuit 2 should be eliminated from Electric Station. This circuit was placed on circuit 37 out of Pleasant Street Substation. This is a 13.8kV circuit, therefore stepdown transformers were used to maintain the 4kV primary voltage of circuit 2. Since circuit 2 will be eliminated from this site, this report will focus on how to eliminate the remaining four 4kV circuits from Electric Station (1, 4, 9, and 13)

4 LOAD PROJECTION

An entire system load projection was completed mid-year of 1997. The historical peak data for the circuits show a 2% yearly increase is a good, but slightly conservative projection. The historical values were obtained and then escalated exponentially by 2% each year up to the year 2013. These projections can be seen in Exhibit D.

Even though this report is primarily focuses on the circuits around Electric Station, load projections were completed for all of the circuits, feeders and station transformers. **These load projections are based upon the system configuration proposed in this report.** These load projections were then compared to their ratings to determine when possible overloads will occur. A complete listing can be seen in Exhibit E.

The following circuits, feeders and transformers show signs of an overload within the time frame of this study.

Circuit/Feeder/Xfmr	Substation	Year of Overload	Per Unit Loading
Ckt. 34	Pleasant St.	2000	1.822
39 Fdr	Summer St.	2003	1.002
Ckt. 10	Canton St.	2003	1.019
50T1	Princeton Rd.	2005	1.017
Ckt. 28	River St.	2008	1.015
Ckt. 6	S. Fitchburg	2010	1.004
35T1	Rindge Rd.	2010	1.004
25T1	River St.	2012	1.008

The circuit 34 overload occurs after circuit 4 is transferred. The overload will be remedied by reconductoring. The loadings on these circuits, feeders, and transformers should be reviewed to determine if these load projections are a true representation of actual loadings.

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5 CIRCUIT CAPACITIES

Due to the proposed system modifications, the circuit capacities for each substation must be revisited. Since this study concentrated on the 4kV circuits out of Sawyer Passway, the updated circuit capacity listings for only the 4kV circuits are shown below. The 13.8kV circuit/feeder capacities will not change as a result of the system modifications.

Due to system modifications, some circuits will no longer exist because they will take on the name of the circuit which they are transferred to. For those circuits, the circuit/feeder which they will be transferred to is listed.

5.1 4kV Circuit Capacities

Circuit #	Transferred To Fdr. Ckt.	Conductor Size	Material	Amps	Major Limiting Factor
1	fdr 3-4 & ckt 1				
2	ckt 37				
4	ckt 34				
5	ckt 26				
6		250	Cu	200	CT's
8	ckt 24				
8A		350	Cu	400	Cable
9	ckt 8A				
10		336.4	AA	200	CT's
11		336.4	AA	280	Recloser
12		250	Cu	200	CT's
13	ckt 8A				
14	fdr 1				
22		2/0	Cu	300/230+	CT's, #2 Cu Sheldon St.
23		250	Cu	300	Cable
24		336.4	AA	360	CT's
26		250	Cu	200	Substation Transformer
34		336.4	AA	450 440	Recloser Xfmr w/ Propane Plant Operating
35		3/0	AA	300+	Wire
36		250	Cu	300	Cable Risers @ Sub

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6 13.8KV NETWORK SYSTEM

A detailed report was completed on the #8 feeder in 1996. This report is not intended to re-engineer the conclusions and recommendations which accompanied that study. The #8 feeder study can be viewed in Exhibit F.

For the sake of this report, it will be assumed that all network feeder positions will be maintained in the new Sawyer Passway substation. This report will detail a solution to enhance the operation of the network system.

6.1 New Circuit 8A (Sawyer Passway)

The #8 feeder study, which was completed in 1996, identified radial load tapped off of the #8 feeder which should be removed. Once all of the radial load is removed from the #8 feeder, the only other radial load tapped off the network system is the old GE Co. building.

The GE building is normally fed from the #11 feeder, with an alternate feed from the #17 feeder. This configuration has proven to be very reliable. At this time, there is minimal load in the building. It is recommended to leave the current configuration. As the GE complex is developed, the service requirements and associated system design should be evaluated.

The new circuit #8A project is designed to remedy the radial load problem on the network as well as ultimately serve circuits 9 and 13 out of Electric Station.

6.1.1 EPR versus PILC Cable

In this project, it will be suggested that EPR cable should be used. The EPR design was developed in 1995 as a replacement for the varnished cambric and PILC cable. The overriding constraint was designing a cable with enough capacity which would fit inside the existing duct system. The underground duct system has a dimension of 3-1/4" square.

EPR cable is more expensive than PILC cable. This cable has a compact design without sacrificing current carrying capacity. The added initial cost of the EPR cable is recovered when it comes to operating expenses. EPR cable, because it is new, will be less likely to fail and the failures that do occur will take much less time to repair.

6.1.2 Project Scope

This project will consist of installing EPR cable to create a new circuit (8A) from Sawyer Passway to the Rollstone Street switchgear. At this point, it will tap into the alternate feed for the #8 feeder from Wallace Road. This will leave PILC cable on the new circuit 8A between the Rollstone Street switchgear and Wallace

Road. This new circuit is in addition to all of the network feeders remaining in service. The Underground Vault and Duct Location drawings are shown in Exhibits G-J.

The new circuit 8A will tie into the end of the #8 feeder so it can be fed from both ends. The configuration will increase the reliability of this line by providing the flexibility required to minimize the number of customers affected by a cable failure and reducing the service restoration time.

This project will include removing all of the radial load off the #8 feeder and relocating it to the new circuit #8A. The new circuit 8A will utilize the existing switches of the #8 feeder. The PILC cable on the #8 feeder should be tapped around the switches and therefore remove them from operation on the #8 feeder. New terminators and splices will be required for this project.

The most economical configuration is to utilize the existing switches on the new circuit 8A. The switches on the new circuit 8A will give the flexibility required to effectively sectionalize in the event of a fault. This will allow the remaining customers to be served while the fault is located and corrected. Due to the redundancy of the network, the #8 feeder does not require the use of these switches. A sketch for this configuration can be seen in Exhibit K.

When this project is designed, the economics of bringing the EPR cable in and out of each manhole versus transition splices should be looked at. Transition splices are very expensive and time consuming. It might be more economical to bring the EPR cable into each manhole and terminate it on the switchgear.

There is one network transformer located beyond the Rollstone Street switchgear (8N13). A section of EPR cable should be run to this transformer such that this network transformer is fed out of Sawyer Passway (#8 feeder). This piece of cable is in addition to the existing #8 feeder; extending it from the Rollstone Street switchgear to pick up this one transformer. The PILC cable tap from the #8 feeder to transformer 8N13 should be cut and capped.

The most reliable way to operate circuit 8A is to have it closed all of the way from Sawyer Passway all of the way to Wallace Road. If protection constraints at Wallace Road do not allow this, then circuit 8A should be opened at the Rollstone Street switchgear. This will be a good point to open the circuit because it is where the EPR and PILC cables come together.

6.1.3 Project Steps

A) Install approx. 6350 feet of EPR cable from Sawyer Passway to the Rollstone Street switchgear on Main Street (New circuit 8A).
B) Remove all switchgear from #8 feeder by tapping around the switchgear.

C) Tap the new circuit 8A onto all of the existing switchgear on the #8 feeder.
D) Install 850 feet of EPR cable from Rollstone Street switchgear to vault 190-V on Main Street. This is to pick up network transformer 8N13 on the #8 network feeder.

6.1.4 Project Cost

This project was estimated for budget purposes by FG&E. The overheads associated with this type of work have been removed. The estimated project cost is:

$252,153

6.1.5 Justification

The addition of the new circuit 8A will enable all of the radial load to be removed from the #8 network feeder. The new circuit will also be used to serve circuits 9 and 13 which are 4kV circuits that originate from Electric Station. In the past, it was the lowest cost alternative to tap the radial load from the network feeders, but it has since created some problems.

In the present configuration, it is difficult to use the alternate feed for the #8 feeder to serve these radial customers from Wallace Road (ultimately the #1 feeder from Beech Street). In order to use the existing backup, all of the network transformers need to be switched off of the network and close the alternate feed. Then all of the radial customers can be picked back up. The network transformers remain out until the source is switched back to Electric Station. This makes for a very lengthy restoration effort.

The new design would leave the network customers on the old PILC cable due to the redundancy of the network. The radial customers will be put on the newer more reliable EPR cable. It is more beneficial to tap the radial customers off the newer cable because they do not have the redundancy of the network.

7 4KV DISTRIBUTION CIRCUITS

The main objective of this study is to identify the most cost effective solution to area distribution needs around the new Sawyer Passway substation site. The construction of a new substation provides the opportunity to reconsider the use of the old cables as the source for the circuits originating from Sawyer Passway. As explained earlier in this report, the 4kV circuits exit Electric Station underground with varnished cambric and PILC (paper-in-lead insulated) cables. These cables are old and there is not much confidence in there operation.

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The varnished cambric and PILC cables have proven to be the cause of many problems in the recent past. Due to the specialized skills required to work on these cables, underground outages take a long time to restore. The reliability of the system would be greatly increased if the cables were eliminated from normal operation. The following projects will detail how the 4kV distribution load, which had originated out of Electric Station, will be served once Sawyer Passway is built. The old cables no longer in use should be removed when the equipment in the building is vacated.

7.1 Circuit 1 – 4kV at Electric Station

7.1.1 Circuit 1 Layout

Circuit 1 exits Electric Station underground and serves distribution load in the vicinity of Middle Street, Worcester Street, Salem Avenue and Nashua Street. This circuit has existing ties with circuit 2 which is now served out of Pleasant Street Substation and circuit 10 out of Canton Street Substation. The circuit diagrams for circuit 1, 10 and 3-4 can be seen if Exhibits L-O.

The underground cable on this circuit is old PILC cable which has experienced problems in the past. This cable runs from Electric Station, down First Street and along Water Street to manhole 115C. This is where circuit 1 ties to circuit 2. An objective of this study is to eliminate the underground cable on this circuit.

In addition to eliminating the PILC cable There are several customers tapped off of the underground cable on Water Street. This issue will be addressed later in this study.

There are two straight forward, obvious, and intuitive ways to serve circuit 1: a) transfer all of the load to circuit 10 out of Canton Street Substation or b) serve some of the load from circuit 10 and the remainder of the load from step transformers installed on Feeder 3-4 out of Beech Street.

7.1.2 Transfer a Portion of Circuit 1 (Electric Station) to Circuit 10 (Canton St.) and the 3-4 Feeder (Beech Street)

The idea behind this project is to serve a portion of circuit 1 by transferring it directly to circuit 10 out of Canton Street. The remaining portion of the circuit will be fed from stepdown transformers installed on the #3-4 feeder.

7.1.2.1 Project Scope

Before the portion of circuit 1 can be tied to circuit 10, there is 200 feet of 250 MCM cable which should be removed and replaced with overhead construction and an airbreak switch. The airbreak will allow this portion of the circuit to be sectionalized from circuit 10. The 638J disconnects should be opened in order to eliminate the underground cable on First Street from normal operation. This configuration transfers the Middle Street portion of circuit 1 to circuit 10, but allows the flexibility to serve this portion of the circuit from the 3-4 feeder.

Transferring this portion of circuit 1 to circuit 10 will increase the 4kV load on Canton Street 500kVA to a level of 1.8MVA. The limiting factor on circuit 10 is a set of 200/5 current transformers. Once these CT's are overloaded, some of the load on circuit 10 can be swapped to circuit 11. The CT's do have an overload rating, therefore the loading on this circuit should be monitored closely. Circuit analysis shows that these CT's will become overloaded in the year 2003. The recloser is only rated for 280A, therefore that should be watched as well.

The second portion of this project consists of extending feeder 3-4 approximately 800 feet and rebuilding 1000 feet of 3 phase overhead construction on circuit 1 along Nashua Street to Worcester Street. Three 333KVA 7.97-2.4kV stepdown transformers should be installed on the corner of South Street and Nashua Street to pick up the remainder of circuit 1. The 333kVA stepdown transformers will be adequate until the year 2008 at which time they will become overloaded and need to be replaced.

This configuration will transfer 500 KVA of load to Canton Street and approximately 800 KVA of load to Beech Street. Once these changes are made, the underground cable can be taken out of service.

Before the project is completed, the protection should be reviewed and updated.

7.1.2.2 Project Steps

A) Circuit 1 - Replace 200' of 250MCM cable with overhead construction
B) Circuit 1 - Extend three phase down Nashua Street with 336.4 AA
C) 3-4 Feeder - Reconductor 1000 feet of 3-4 Feeder to 336.4 AA
D) 3-4 Feeder - Extend 3-4 Feeder 800 feet with 336.4 AA
E) 3-4 Feeder - Install 3 - 7.97-2.4kV 333kVA stepdown transformers
F) Circuit 1 - Close new disconnects on Water Street (Tie to Ckt. 10)
G) Circuit 1 - Open the 638J disconnects
H) Circuit 1 - Open 6722 (source side) disconnects

7.1.2.3 Project Cost

This project was estimated for budget purposes by FG&E. The overheads associated with this type of work have been removed. The estimated project cost is:

$58,235

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7.1.3 Justification

If circuit 1 was transferred in its entirety to Canton Street, the underground cable would need to be replaced. The decision to split circuit and transfer some of it to the 3-4 feeder ends up being a more cost effective solution and complements the future goals of expanding 13.8kV throughout the system.

This proposed circuit split will eliminate the underground cable from normal operation which will increase the reliability of circuit 1. This cable should be remove3d when the building is vacated. This is another step towards eliminating the added expense of 4kV transformation at Sawyer Passway.

7.2 Circuit 2 – 4kV Electric Station

By the end of the year 1999, circuit 2 out of Electric Station will be transferred to circuit 37 (13.8kV) out of Pleasant Street. As a part of this project, 3-250kVA, 7.97-2.4kV stepdown transformers were added to circuit 37 to feed circuit 2. This circuit diagram can be seen in Exhibit P.

Circuit analysis has shown that there will be a couple of problems on circuit 37 in the year 2000. First, the 100kVA stepdown transformer located on Pearl Hill Road will become overloaded (114%). This transformer should be replaced with a 167kVA stepdown transformer.

Secondly, a low voltage problem (116.7V) has been identified on Pearl Hill Road. A 100kVAR capacitor bank installed on the corner of Pearl Hill Road and Steward Road will provide the voltage support necessary to remedy the voltage problem.

In the past, circuit 2 has experienced many problems which were related to the old PILC cable originating at Electric Station. This project was completed in an effort to eliminate the old PILC underground cables on this circuit which will in turn increase the reliability of the circuit.

For the sake of this study, it was assumed that circuit 2 has already been removed from Electric Station. There are several large customers which are tapped off the underground cable. All of these customers should be removed from this cable before the end of 1999.

There is some old cable which has been abandoned due to this project. This cable should be removed when the building is vacated.

7.3 Circuit 4 – 4kV Electric Station

7.3.1 Circuit 4 Layout

Circuit 4 originates at Electric Station and serves load in the vicinity of Summer Street, Winter Street, Boutelle Street, and Jackson Avenue. This circuit has existing ties with circuit 34 out of Pleasant Street and circuit 6 out of South Fitchburg substations. The circuit diagrams for circuits 4 and 34 can be seen in Exhibits Q-R.

Once again, this circuit has old PILC underground cable originating from Electric Station. The following solution will eliminate the need for this cable during normal operation

7.3.2 Transfer Circuit 4 (Electric Station) to Circuit 34 (Pleasant Street)

This circuit transfer is actually a very straight forward project. The project will consist of transferring the existing load on Circuit 4 out of Electric Station to Circuit 34 out of Pleasant Street Substation. Circuit 4 has an existing tie with Circuit 34 at pole 1991. Transferring all of the Circuit 4 load to Circuit 34 will eliminate the need for the old PILC cable.

7.3.2.1 Project Scope

Upon transferring circuit 4 to circuit 34, an overload occurs on circuit 34. This overload should be fixed by reconductoring 5000 feet of #2 Cu conductor with 336.4 AA conductor. The reconductoring will begin at Pleasant Street substation and continue along Lunenburg Street to Boutelle St. This reconductoring will eliminate the overload on circuit 34 and eliminate some voltage problems which arise when circuit 4 is tied to circuit 34.

The circuit transfer will add approximately 1.5 MVA onto the Pleasant Street 69-4kV transformer. Circuit 34 has an existing load of 1.1 MVA, so this transfer will increase this load to approximately 2.6 MVA. The transformer is rated for 3.5MVA.

The propane plant located at Pleasant Street substation, which does not always operate, is served by a 300kVA transformer directly off of the 4kV bus. Even when this plant is in operation, the transformer has future capacity.

Circuit analysis has shown that there is a voltage problem (117.0 V) on circuit 4 in the vicinity of Summer Street. A 300kVAR capacitor bank installed on the corner of Summer Street and Fifth Street will provide enough voltage support to solve the problem.

This project is changing the overall configuration of these circuits. When the project is designed, the circuit protection should be reviewed.

7.3.2.2 Project Steps

A) Circuit 34 - Reconductor 5000 circuit feet (Pleasant St. to Boutelle St.)
B) Circuit 4 - Install 300KVAR capacitor bank on the corner of Summer St. and 5th St.
C) Circuit 4 - Close the 1191J disconnects
D) Circuit 4 - Open the 286J disconnects

7.3.2.3 Project Cost

This project was estimated for budget purposes by FG&E. The overheads associated with this type of work have been removed. The estimated project cost is:

$63,034

7.3.3 Justification

This circuit transfer is an obvious solution to eliminating this 4kV circuit from Sawyer Passway. The only other place that circuit 4 could be transferred to is circuit 6 from South Fitchburg substation. The South Fitchburg transformer is only a 2500kVA unit, therefore, there is not enough capacity to serve circuit 4 as well. The old 4kV cable originating from Electric Station should be removed when the building is vacated.

Another solution to serving circuit 4 would be to use stepdown transformers off of the #40 feeder. The #40 feeder is a uni-point grounded feeder served from Summer Street. In order to install stepdown transformers on this feeder, they would have to be fully rated stepdown transformers with sophisticated protection on both the high voltage and low voltage sides. This would be an extremely expensive solution. The ultimate goal is to change Summer Street to an effectively grounded station, therefore this equipment would be wasted.

This circuit transfer is a very straight forward cost effective project. This transfer will add approximately 1.5 MVA onto the Pleasant Street 69-4kV transformer. Circuit 34 has an existing load of 1.1 MVA, so this transfer will increase this load to approximately 2.6 MVA. This transformer is rated for 3.5 MVA, therefore this transfer still leaves plenty of future capacity at this station.

This project does require some modifications in order to make it work, but the modifications fall in line with the future goals of this substation. The future goal for this substation is to convert circuit 34 to 13.8kV. This conversion would need to go as far as needed to serve the rest of the circuit with stepdown transformers. This would eliminate 4kV entirely from Pleasant Street substation. The 69-13.8kV transformer has enough capacity for this conversion to occur.

7.4 Circuit 9 and Circuit 13 – 4kV Electric Station

7.4.1 Circuit 9 Layout

Circuit 9 originates at Electric Station and serves the Elm Street, Mechanic Street, and Academy Street areas. This circuit has existing ties with circuit 13 out of Electric Station, circuit 22 out of Nockegė and circuit 35 out of Rindge Road substation. The circuit 9 diagrams can be seen in Exhibit S.

As with all of the other 4kV circuits out of Electric Station, this circuit has a large amount of PILC cable. All of this cable should be removed when the building is vacated. Over the years, the amount of failures has decreased the confidence in this cable. Once again, this solution will eliminate the need for this cable to be used under normal operating conditions.

7.4.2 Circuit 13 Layout

Circuit 13 originates from Electric Station and serves the Willow Street, Blossom Street, and Mt. Vernon Street areas. This circuit has existing ties with circuit 9 out of Electric Station and circuit 2 out of Electric Station. The circuit 13 diagrams can be seen in Exhibit T.

Once again, this circuit has some PILC cable originating from Electric Station. Over the years, the reliability of this cable has been decreasing to a point where it is justifiable to eliminate this cable.

7.4.3 Serve Circuit 9 and Circuit 13 From New Circuit 8A

Over the years, the #8 network feeder originating from Electric Station has been used to serve radial load. This has created problems on the network system. A detailed analysis was developed as a result of several outages on the PILC cable.

This project is designed to use the new circuit 8A out of Sawyer Passway to serve the load on circuits 9 and 13. This new underground circuit will be located nearby on Main Street. Since the side streets up to circuits 9 and 13 have spare ducts available, this turns into a very economical solution to serving circuits 9 and 13.

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7.4.3.1 Project Scope (Circuit 13)

Part one of this project will consist of serving circuit 13 off of the new circuit 8A using 2 banks of 7.97-2.4kV stepdown transformers. Two stepdown banks will be required due to loading as well as to increase reliability.

A 500 foot section of EPR cable should be installed from MH 9-A on Main Street to MH 71-A on Willow Street. A riser pole with 3-333kVA stepdown transformers should be installed on the corner of Willow Street and Morris Street. Existing spare ducts will accommodate this.

To serve the remaining portion of circuit 13, a 400 foot section of EPR cable should be installed from MH 21-A on Main Street to MH 132-A on Pleasant Street. A riser pole with 3-167kVA stepdown transformers should be installed on the corner of Pleasant Street and Goodwin Street. Existing spare ducts will accommodate this.

A 1500 foot, three phase overhead extension on Mt. Vernon Street from Simonds Road to the stepdown bank will be required to pick up the stepdown bank. This should be installed with a minimum of 336.4 AA conductor. The 797 disconnects should be opened to split the circuit. The circuit diagram for circuit 13 can be seen in exhibit G.

7.4.3.2 Project Scope (Circuit 9)

The second part of this project will consist of serving circuit 9 from the new circuit 8A. A 600 foot section of EPR cable should be installed from MH 34-A on Main Street to MH 124-A on Academy Street. Existing spare ducts will accommodate this.

Two stepdown banks will be installed in order to split up the circuit. Two stepdown banks are required due to loading and as well as to increase the reliability of the circuit.

One bank of 3-250kVA stepdown transformers should be installed on Elm Street at the corner of Elm and Academy Street. Load projections show that this bank of stepdown transformers will experience an overload in the year 2004. Loading on this transformer bank should be monitored to determine if the load projections are correct.

The second set of 3-250kVA stepdown transformers should be installed on Academy Street at the corner of Elm Street and Academy Street. The circuit diagram for circuit 9 can be seen in exhibit H.

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7.4.3.3 Project Steps

Circuit 13

A) Install 500' of EPR cable from MH 9-A (Main St.) to MH 71-A (Willow St.)
B) Install riser pole and 3-333kVA stepdown transformers on the corner of Willow Street and Morris Street
C) Install 400' of EPR cable from MH 21-A (Main St.) to MH 132-A (Pleasant St.)
D) Extend three phase (1500') overhead on Mt. Vernon Street, down Weymouth Street, Goodwin Street, to Pleasant Street
E) Install riser pole and 3-167kVA stepdown transformers on the corner of Goodwin Street and Pleasant Street
F) Open 797 disconnects to split up circuit

Circuit 9

A) Install 600' of EPR cable from MH 34-A (Main St.) to MH 126-A (Academy St.)
B) Install a riser on Academy Street
C) Install 3-250kVA stepdown transformers on Academy Street
D) Install 3-250kVA stepdown transformers on Elm Street
E) Split circuit between the two stepdown banks

7.4.3.4 Project Cost

This project was estimated for budget purposes by FG&E. The overheads associated with this type of work have been removed. The estimated project cost is:

$148,571

7.4.4 Justification

The design of this project will utilize the new circuit 8A which is already required for different reasons. This new circuit would be underutilized if it only served the radial load taken off of the network system.

By using the new circuit, it is beginning to expand 13.8kV north through the system. This will help facilitate the ultimate goal of eliminating the 4kV substations and replace them with 13.8kV circuits.

The reason for two sets of stepdown banks on each circuit is two-fold. One, the amount of load on these circuits is approximately 1500kVA each. At this load level, it is easier to install two stepdown banks rather than try to install one. The

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second reason for multiple stepdown banks is reliability. The more stepdown banks there are serving a circuit, the more reliable the circuit is.

Both portions of this project would also work with the use of padmounted transformers. The difficulty with padmounted transformers is the fact that an easement needs to be purchased and a pad poured in order to place the transformer. Both options should be considered when this project is engineered.

Another solution to serving circuits 9 and 13 came from circuit 35 out of Rindge Road. Circuit 36 out of Rindge Road has been converted to 13.8kV to serve the new school. The idea was to extend the conversion to circuit 35 and pick up circuits 9 and 13. This would require reconductoring on the #41 Feeder out of Wallace Road. This line would need to be reconductored while it was energized because it is the only supply to Rindge Road.

The long term goal for Rindge Road is to convert it to a 69-13.8kV substation, therefore, the reconductoring would be wasted. This would be an extremely expensive project due to the conversion to 13.8kV and live line reconductoring.

Many different alternatives were looked at in determining how to serve both of these circuits. The future goal for these circuits will be to keep converting them to 13.8kV as voltage and loading problems arise.

7.5 Capital Budget Project Summary

Project	***Cost***
Circuit 1 Transfer	$ 58,235
Circuit 4 Transfer	$ 63,034
New Circuit 8A	$ 252,153
Circuit 9 & 13 Transfer	$ 148,571
Total	**$ 521,993**

8 SYSTEM IMPROVEMENTS

Circuit analysis for this study has revealed some problems which are not directly related with the Sawyer Passway project. While these problems were identified, they were not fully examined to determine the most cost effective solutions. The suggested solutions below are possible solutions, but each problem should be analyzed again to determine the most cost effective system improvement options.

Each problem identified is accompanied by the year in which a system improvement is required. These problems assume the new system configuration.

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Year	Circuit	Sub	Location	Problem	System Improvement Option
2000	26	W. Fitchburg	Sheldon Rd.	Low Voltage (114.0V)	100kVAR Cap on Sheldon Road
2000	22	Nockege	Ashburnham Hill Rd.	Low Voltage (109.4V)	Recon. 4000' of #6 Cu to 336.4 AA
2000	22	Nockege	Ashburnham Hill Road	Low Voltage (115.8V)	100kVAR Cap corner of Ashburnham Hill Rd. and Williams Rd.
2000	24	Nockege	S/S to Kimball St.	Overload (120%)	Reconductor 1300' of 1-1/0 ACSR+2-#6 Cu to 336.4 AA
2000	14	Beech St. (Feeder #1)	Pratt Road	Overload (119%)	Replace 3-250kVA steps w/ 3-333kVA steps
2002	4 (34)	Pleasant St.	Summer St.	Low Voltage (115.5kV)	300kVAR Cap corner of Summer St. and Milton St.
2004	9 (8A)	Sawyer Passway	Elm St.	Overload (103%)	Replace 3-250kVA steps with 3-333kVA steps
2006	22	Nockege	Ashburnham Hill Road	Low Voltage (116.2V)	Increase 100kVAR cap to 200kVAR cap corner of Ashburnham Hill Rd. and Williams Rd.
2006	14	Beech St. (Feeder #1)	Pratt Road	Overload (103%)	Replace 3-333kVA steps with 3-500kVA steps
2008	1	Beech Street (3-4 Feeder)	Nashua St.	Overload (104%)	Replace 3-333kVA steps with 3-500kVA steps
2008	37	Pleasant St.	Pearl Hill Road	Overload (102%)	Replace 100A regulator with 150A regulator
2011	4 (34)	Pleasant St.	Boutelle St.	Low Voltage (114.8kV)	Add 150A regulators on corner of Boutelle St. and Winter St.
2011	4 (34)	Pleasant St.	Townsend St.	Low Voltage (114.8V)	300kVAR cap on Townsend St.
2011	26	W. Fitchburg	Sheldon Road	Low Voltage (117.2V)	Increase 100kVAR cap to 200kVAR
2012	26	W. Fitchburg	River St.	Overload (107%)	Reconductor 100' of 3-#2 Cu to 336.4 AA

9 SAWYER PASSWAY SUBSTATION

The new Sawyer Passway site will be located on the same parcel of land as Electric Station. The new station will be a 69-13.8kV Delta-Way effectively grounded station. There has been an ongoing effort to install neutral conductors on all of the overhead and underground facilities which are not effectively grounded. This will include effectively grounding Summer Street substation which is uni-point grounded through a resistor.

The proposed configuration for Sawyer Passway is a two transformer line-up with one 69kV transmission line (06 Line) as the 69kV only source. The ultimate goal is to have two 69kV lines from Summer Street serving Sawyer Passway. The backup for Sawyer Passway will come from the 3A and 9 feeders to Summer St.

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The 13.8kV bus will be required to have a minimum of 9 circuit/feeder exits. Space should be left for future circuit/feeder exits. These will be a combination of overhead and underground exits. It has yet to be determined how these exits will be designed.

10 EFFECTIVELY GROUNDED SYSTEM

In and effectively grounded system, the ratio of the zero sequence reactance to the positive sequence reactance should be kept below 3 ($X0/X1 < 3$) and the ratio of the zero sequence resistance to positive sequence reactance should be kept below 1 ($R0/X1 < 1$). These ratios limit the voltage rise experienced under fault conditions.

The benefits of an effectively grounded system are to enable lower insulation levels, eliminate arcing grounds, double faults are unlikely, lightening protection will operate more efficiently, and with proper considerations effectively grounded systems be connected to resistance and reactance grounded systems.

10.1 Existing System Configuration

The existing configuration at Electric Station is a 69-13.8kV Wye-Delta transformer. This means that the Electric Station is not grounded at all. Summer Street is uni-point grounded through a grounding resistor. The future goal is to effectively ground Sawyer Passway and Summer Street.

10.2 System Modifications

To establish an effectively grounded system at Sawyer Passway, the following system modifications are required. 69-13.8kV <u>Delta-Wye</u> transformers should be installed. This will decrease the ratios to the point where the substation is considered to be effectively grounded.

In order to effectively ground the URD cables, the lead sheaths (PILC cable) and the 1/3 copper strapping (EPR cable) should be bonded at all splices. An additional piece of 4/0 Cu ground wire should be installed in the manhole and duct bank system. The lead sheaths and 1/3 copper neutrals should be bonded to the additional neutral/ground conductor. This will ensure ground conductor continuity. Where the condition of the neutral conductor is in question, the wire should be replaced before energizing Sawyer Passway due to increased fault currents.

The existing work practices by FG&E on overhead construction appear to be adequate when it comes to effectively grounded circuits. The following points should be enforced on overhead construction: 1) always use a ground rod at all equipment locations and 2) a minimum of 4 ground rods should be installed for each circuit mile.

Establishing an effectively grounded system at Summer Street substation will not be as straight forward as Sawyer Passway. Summer Street does not need to be effectively grounded in order to put Sawyer Passway in service. For protection purposes, it is in the best interest of the system to effectively ground Summer Street within the next several years.

11 FINAL SAWYER PASSWAY CONFIGURATION

The final system configuration will have successfully removed all of the 4kV circuits from Sawyer Passway substation. This was accomplished by transferring:

Circuit 1	to	Feeder 3-4 and Circuit 10
Circuit 2	to	Circuit 37
Circuit 4	to	Circuit 34
Circuit 9	to	Circuit 8A
Circuit 13	to	Circuit 8A

A new circuit 8A will be installed from Sawyer Passway and connect back into the #8 network feeder. This circuit will be used to remove the radial load from the #8 network feeder. There will be two radial customers remaining on the network system once the project is completed.

The GE building is not in use right now, but upon development, may also be removed from the network system. The service requirements at the time will govern how the building will be served. The library is now served off of the network. This load can be placed on either circuit 8A or the secondary network system. The most economical solution should be used. This study does not detail a plan to remove the library from the network system.

All of the network feeder positions (8,10A, and 11) will be maintained in the new substation. The 10/113 breaker position splits into feeders 10A and 10B. When designing the new substation, it is recommended to have separate breaker positions for feeders 10A and 10B.

The backup feeders to Summer Street substation (3A and 9) will also be maintained. The new configuration will have the 3A and 9 feeders operated in the normally open position with an automatic closing scheme. This will eliminate the need for higher equipment ratings due to increased fault current. This will also eliminate circulating current between Sawyer Passway and Summer Street substations under light loading conditions.

The #7 feeder was tested around the end of 1998. This feeder is a 13.8kV tie between Beech Street and Electric Station. The testing of this cable identified that the cable is no longer suitable as a tie and should be decommissioned. Therefore, a breaker position will not be maintained at the new substation.

Feeders 10 and 17 are 13.8kV feeds to Nockege Substation. Both of these breaker positions will be maintained in the new substation design. All in all, 9 breakers are required for circuit/feeder exits.

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12 ACTION ITEMS

CIRCUIT	PROJECT	COMPLETION DATE
1	Circuit Transfer	9/1/00
37	Circuit Improvements to Eliminate Overloads and Voltage Problems	6/1/00
4	Circuit Transfer	9/1/00
8A	New Circuit	9/1/00
9	Circuit Transfer	9/1/00
13	Circuit Transfer	9/1/00
14	Replace Stepdowns – Overload	6/1/00
22	Circuit Improvements to Eliminate Voltage Problems	6/1/00
24	Reconductor to Eliminate Voltage Problems	6/1/00
26	Capacitor Installation	6/1/00

13 CONCLUSION

In conclusion, through the use of the economical projects detailed in this report, all of the 4kV circuits which originate out of Electric Station can be served from other sources. The added substation cost for maintaining the 4kV circuits at Sawyer Passway was estimated at one million dollars without overheads.

For half of the price of the substation work, all of the 4kV circuits can be served from other sources. These project not only remove 4kV from Sawyer Passway, they also fix several system problems.

The new circuit 8A project remedies a problem which has been detailed in several system studies. This project eliminates all of the radial load off of the #8 feeder which increases the reliability and decreases the restoration time. This would be an expensive project if it was only designed to remove the radial customers from the network. This project becomes more economical because it will be used to serve two 4kV circuits (9 and 13) which now originate out of Electric Station.

This report has detailed four economical projects. Several other alternative were analyzed, but based upon use of existing facilities, age/condition of plant and providing room for growth, these four projects have become the best projects.

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14 EXHIBITS

Exhibit	Description	Drawing No.
A	Parsons Power Group Inc. Study	
B	System Oneline Diagram (Simplified)	FCYTD001
C	Electric Station Oneline	FAS02D1
D	Load Projections	
E	Loading in Per Unit of Rating	
F	#8 Feeder Study	
G	Underground Vault and Duct Location	FDNT0001
H	Underground Vault and Duct Location	FDNT0002
I	Underground Vault and Duct Location	FDNT0003
J	Underground Vault and Duct Location	FDNT0004
K	Circuit 8A Sketch	
L	Circuit Diagram #1	FDC01
M	Circuit Diagram #10	FDC10
N	Circuit Diagram #3-4 (Sheet 1 of 2)	FDC03A
O	Circuit Diagram #3-4 (Sheet 2 of 2)	FDC03B
P	Circuit Diagram #37, #2	FDC37C
Q	Circuit Diagram #4	FDC04
R	Circuit Diagram #34	FDC34
S	Circuit Diagram #9	FDC09
T	Circuit Diagram #13	FDC13
U	4kV Circuit Ties	FDYDM001
V	13.8kV Circuit Ties	FDYDM002

EXHIBIT A

DRAFT COPY

ELECTRIC STATION PLANNING STUDY

FOR

FITCHBURG GAS AND ELECTRIC LIGHT COMPANY

DRAFT COPY

PREPARED BY

PARSONS POWER GROUP INC.

APRIL, 1997

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I. EXECUTIVE SUMMARY

The purpose of this study was to develop a conceptual, long term, cost-effective system expansion and development plan for the electric transmission and distribution facilities currently existing at the Electric Station and emanating from Sawyer Passway. This work is necessitated by the environmental remediation activity to be undertaken at the site.

The following goals and objectives formed the basis of the study:

- Maximize the capability of the existing transmission and distribution facilities.
- Provide automatic voltage control.
- Adhere to Unitil's planning guidelines and/or industry accepted standards.
- Establish an effectively grounded system for the 13.8kV circuits presently emanating from the Electric Station.
- Remove the radial loads from the network feeders in the downtown area of Fitchburg.
- In accordance with Unitil guidelines, make provisions for using FG&E's existing mobile and spare equipment.

Since it will be retired within a few years, the operation of the #7 turbine generator which is located at the Sawyer Passway site was not considered in our analyses.

The following three scenarios were investigated:

1. Install a new 69kV/13.8kV/4.16kV substation at the Sawyer Passway site.

2. Install two new substations, one at the Sawyer Passway site and one adjacent to the existing Wallace Road Substation site (on FG&E owned land). To supply the Wallace Road site, a double circuit 69kV transmission line would be extended from the River Street substation to Wallace Road.

3. Install a new 69kV/13.8kV substation at the Wallace Road site. Some of the existing Electric Station loads will be transferred to this new site and some to the Summer Street

Substation. The 4kV circuit loads at the Electric Station would be transferred to 4kV circuits supplied from other substations, converted to 13.8kV or supplied by step down transformers. A double circuit 69kV transmission line would be extended from the River Street Substation to the Wallace Road site.

Based upon our review, we recommend the installation of a new 69kV/13.8kV/4.16kV substation at the Sawyer Passway site and in the vicinity of the existing cooling tower, which is scheduled for demolition. Voltage regulation would be provided by transformer on load tap changers on each of two 10/14 MVA transformers. The estimated cost for this installation is $3.0 million.

Our recommendation is based on the following:

1. Most cost effective.

2. Best use of existing 69kV transmission facilities, as well as the existing 13.8kV and 4.16kV underground station getaways.

3. Will take full advantage of existing station ties between Sawyer Passway, Beech Street Substation and Summer Street Substation.

4. Very good site location; clean and flat with easy access.

5. Future site developer will have ready access to reliable power supply.

6. Will eliminate the need for future 69kV/13.8kV substation at Wallace Road site.

7. An additional long term advantage is that it will facilitate the transfer of load and will ultimately eliminate the need for the Wallace Road and Nockege Substations. Both of these stations are old and, if not replaced, in need of significant upgrade. Part of this load could also be supplied by the Beech Street Substation. The new Princeton Road Substation is presently supplying some of the former Beech Street load.

We would recommend that FG&E consider the use of a single 21/28/35 MVA transformer rather than the two 10/14 MVA transformers in order to achieve a savings of approximately 10%. If FG&E is interested in considering this approach, it should be addressed in more detail in the follow-up studies.

It is also recommended that FG&E investigate the re-commissioning of Feeder #7 which runs direct between the Electric Station and the Beech Street Substation. This would provide additional backfeed capabilities.

In order to support FG&E's enhancement of the downtown secondary network system, we recommend that Feeder #8 be used to supply the radial loads presently connected to the network Feeders 10-113 and 11. In addition, Feeder 8's network loads should be transferred to Feeders 10-113 and 11. The only non-network load remaining on these feeders will be the General Electric Company (Feeder 11). In the long term, as load is transferred off of Nockege Substation, the General Electric Company should be transferred to Feeder 10 as the primary supply and, as at present, backed up by Feeder 17 via an automatic transfer scheme.

To establish an effectively grounded system, it is recommended that: (1) a delta-grounded wye 69kV/13.8kV transformer be installed at the proposed new Sawyer Passway Substation; (2) a new 4/0 bare copper conductor be installed in the manhole and duct bank system emanating from the Sawyer Passway site and bonded to the existing ground wire to ensure ground/neutral continuity throughout the system and; (3) to verify (or provide where necessary) the neutral/ground wire is continuous in the overhead portions of the circuits.

II. REVIEW OF EXISTING FACILITIES

Sawyer Passway/Electric Station

In accordance with our scope of work, we conducted a physical review of the electric facilities at this site. We have concluded that with the possible exception of the transformers being used as spares, the major electric components have no value for re-use in any of the proposed expansion plans. The age of the equipment (30 to 50 years old), lack of availability of spare parts and condition (serious deterioration, in many cases) make them unsuitable for any further consideration. The 69kV to 13.8kV and 13.8kV to 4.16kV transformers may have some value as spares, depending upon their condition (verified by electrical tests) and whether or not they would be suitable for other FG&E locations. The final determination should be made in the more detailed follow-up study.

Per our discussion with FG&E personnel, the existing 13.8kV and 4.16kV paper insulated lead cables (PILC) have been determined to be in very good condition based on independent laboratory tests. Therefore, these cabled would be suitable for re-use.

We have also been advised that the manhole and duct bank system (including the concrete encased duct bank crossing over the Nashua River) is also in good condition and is suitable for continued use.

Wallace Road/Nockege Substations

While a more cursory review was made of this equipment, it appears that the age and a limited amount of maintenance has taken its toll on this equipment. While still serviceable, it is recommended that this equipment be gradually phased out and the loads transferred to adjacent substations within the next three to six year period. These loads can be transferred to the Beech Street Station and the proposed new substation at Sawyer Passway.

III. DESCRIPTION AND ANALYSIS OF VARIOUS SCHEMES FOR REPLACING THE SUBSTATION FACILITIES AT THE ELECTRIC STATION

In the course of our investigation, three different schemes were identified and analyzed. Due to the age and condition of the existing equipment, its re-use (with the exception of possible use as spares) was eliminated from consideration in any of the schemes.

The first scenario looked at was a new substation located at the Sawyer Passway site. This approach maximizes the use of existing 69kV transmission facilities, as well as the 13.8kV and 4.16kV distribution circuit main getaways. This location also provides a good, clean level site. It also proved to be the most cost effective and will provide a ready source of power for future site development. It should also eliminate the need for a future substation at the Wallace Road site. In fact, it will facilitate the ultimate elimination of the existing Wallace Road and Nockege Substations. This location would also take advantage of the strong ties already existing between the Summer Street Substation, Beech Street Substation and the Electric Station.

We also looked at the option of installing a single, large transformer (21/28/35MVA) at this location rather than two 10/14MVA units. Our preliminary review indicated that savings of approximately 10% could be realized. A more detailed analysis, including firm price quotes, would be required to more accurately determine the amount of savings.

The second major alternative investigated was a variation of the first scheme. Instead of a single substation at the Sawyer Passway site, the installation of two smaller substations was investigated; one to be installed at the Sawyer Passway site and a second at the Wallace Road site where FG&E owns additional land adjacent to the existing substation. This scheme would also require that the 69kV transmission system be extended from the River Street Substation to the Wallace Road site, a distance of approximately 0.5 mile. Our estimated cost for this transmission line extension was based on a double circuit steel pole configuration. The new Wallace Road Substation would supply the loads presently served by the existing Wallace Road Substation, as well as the loads at the Nockege Substation.

The new Sawyer Passway Substation would supply Feeders 8, 10-113 and 11, as well as the existing 4kV load at the Electric Station. One of the drawbacks to this scheme is the suitability of the Wallace Road site. Our concerns are based on the significant elevation changes, the narrowness of the site and its proximity to the street which lends itself to potential vandalism. The use of this site would result in higher engineering and construction costs. Providing access to FG&E's mobile station equipment will also be more difficult.

The third scheme investigated was the installation of a new 69kV/13.8kV substation at the Wallace Road site. The objective of this approach was to provide a totally clear site at Sawyer Passway. The majority of the existing Electric Station loads would be transferred to this substation and the remaining load to the Summer Street Substation via Feeders 3A and 9. Since this scheme would require more space than scheme 2, this raises even greater concerns over the suitability of the site. In addition, with this scheme, the existing backup capability between the Beech Street Substation, the Summer Street Substation and the Electric Station site are lost.

The cost estimates for these schemes are included in Section IV.

IV. CONSTRUCTION COST ESTIMATES

Construction cost estimates have been prepared for the various alternatives that have been investigated. Substation costs and transmission line costs are listed separately.

1. New Substation at Sawyer Passway Site

a.	Transformers: 2 - 10/14 MVA, 69kV/13.8kV with OLTC and 1 - 5 MVA 13.8kV/4.16kV	$ 600,000
b.	2 Circuit Switchers - 1200 AMP, 72.5kV	75,000
c.	15kV Metal Clad Vacuum Switchgear Lineup - 15 Position	450,000
d.	5kV Metal Clad Vacuum Switchgear Lineup - 6 Position	202,000
e.	Prefabricated Metal Building	100,000
f.	Civil/Structural - Grading, Fence, Grounding, Foundations, Oil Containment, Terminal Structure	350,000
g.	Electrical - Misc. 69kV Switches, Mobile Sub Taps, Cap Banks	170,000
h.	Electrical Installation, Testing, Commissioning	500,000
i	Cable Getaway Ties to Existing Systems	170,000
j.	Engineering, Project Management	$ 275,000
	SUBTOTAL:	$2,892,000
	Contingency - Approx. 15%	$ 408,000
	TOTAL:	$3,300,000

2. **Two New Substation Sites - One at Sawyer Passway Site and One at Wallace Road Site**

a.	Transformers: 2 - 10/14 MVA, 69KV/13.8kV with OLTC and 1 - 5 MVA 13.8kV/4.16kV	$ 600,000
b.	2 Circuit Switchers - 1200 AMP, 72.5kV	75,000
c.	15kV Metal Clad Vacuum Switchgear Lineup - 20 Position	600,000
d.	5kV Metal Clad Vacuum Switchgear Lineup - 6 Position	202,000
e.	Prefabricated Metal Building	150,000
f.	Civil/Structural - Grading, Fence, Grounding, Foundations, Oil Containment, Terminal Structure	525,000
g.	Electrical - Misc. 69kV Switches, Mobile Sub Taps, Cap Banks	400,000
h.	Electrical Installation, Testing, Commissioning	750,000
i	Cable Getaway Ties to Existing Systems	300,000
j.	Engineering, Project Management	$ 400,000
	SUBTOTAL:	$4,002,000
	Contingency - Approx.. 15%	$ 598,000
	TOTAL:	$4,600,000

3. **New Substation at Wallace Road Site**

a.	Transformers: 2 - 10/14 MVA, 69kV/13.8kV with OLTC and 1 - 5 MVA 13.8kV/4.16kV	$ 500,000
b.	2 Circuit Switchers - 1200 AMP, 72.5kV	75,000
c.	15kV Metal Clad Vacuum Switchgear Lineup - 15 Position	450,000
d.	Prefabricated Metal Building	100,000
c.	Civil/Structural - Grading, Fence, Grounding, Foundations, Oil Containment, Terminal Structure	450,000
f.	Electrical - Misc. 69kV Switches, Mobile Sub Taps, Cap Banks	325,000
g.	Electrical Installation, Testing, Commissioning	500,000
h.	Cable Getaway Ties to Existing Systems	250,000
i.	Engineering, Project Management	$ 300,000
	SUBTOTAL:	$2,950,000
	Contingency - Approx.. 15%	$ 450,000
	TOTAL:	$3,400,000

4. **69kV Double Circuit Transmission Line from River Street Substation to Wallace Road Site**

a.	Transmission Line - (For Pricing Details See Attached Cost Breakdown at end of this section)	$ 323,000
b.	Deadend Structures - River Street and Wallace Road	$ 100,000
	TOTAL:	$ 423,000

Estimates 5. and 6. are for information only and may be helpful for future planning.

5. **69kV Double Circuit Transmission Line from Wallace Road to Rindge Road**

a.	Transmission Line (For Pricing Details See Attached Cost Breakdown at end of this section)	$2,067,000
b.	Deadend Structures - Wallace Road and Rindge Road	$ 100,000
	TOTAL:	$2,167,000

6. **Install Second 69kV Transmission Line from Summer Street Substation to Sawyer Passway**

a.	Transmission Line (For Pricing Details See Attached Cost Breakdown at end of this section)	$ 211,000
b.	Deadend Structures - Summer Street and Sawyer Passway Switching Facilities at Sawyer Passway	200,000
	TOTAL:	$ 411,000

7. **Transfer of Electric Station 4kV Loads**

If a new substation is not installed at the Sawyer Passway site, the existing 4kV Electric Station loads would have to be transferred to a new source of supply. While a comprehensive, detailed study of the preferred methods of transferring the loads was not undertaken, it is assumed that the existing 4kV loads would be transferred to adjacent feeders, converted to 13.8kV or supplied by stepdown transformers. We have estimated the costs at approximately $250,000 per circuit for each of the five circuits or $1,250,000 total.

Summary of Total Construction Costs for the Various Alternative Schemes

1.	Recommended Plan: New Sawyer Passway Site	$3,300,000
2.	Sawyer Passway and Wallace Road Substations	$4,600,000
	Deadend Structures and Transmission Line Costs	423,000
	TOTAL:	$5,023,000
3.	Wallace Road Substation	$3,400,000
	Deadend Structures and Transmission Line Costs	423,000
	Cost to Transfer Electric Station 4KV Loads	1,250,000
	TOTAL:	$5,073,000

Client: Fitchburg Gas and Electric | By: PEB Date: 04/07/97
Subject: Estimated Cost for a Rebuilt Single Circuit 69 kV Transmission Line....Summer Street to Electric Station | Chk'd: AD

Assumptions:

a) Voltage - 69 kV
b) Number of circuits - one
c) Reuse Existing Structures
d) Relocate 13.8 kV to lower position
e) Reuse Crossing Structures are required
f) Transmission line routing is angular
g) Digging is easy to moderately difficult
h) The structures are wood pole
i) Surveying & Permits is 5% of direct cost
j) Engineering is 10% of direct cost
k) Construction Management is 10% of direct cost
l) Contingency is 20 %

ASSUMED LINE PARAMETERS

Structure Type	Type of Terrain	Height Above Ground	Foundation Type: Suspension Structure	Foundation Type: Angle Structure	Number of Poles: Suspension Structure	Number of Poles: Angle Structure	Conductors Per Circuit	Shield Wires Per Circuit	New Structures: Suspension Structure	New Structures: Angle Structure	Right-of-Way Width Feet	Normal Loading MVA
Single Pole w/Crossarms	Moderately Flat	45	Direct Bury	Direct Bury	1-Wood	1- Guyed	3-656.5 Kcmil	1- 3/8" Steel	4	2	60	60

ESTIMATED INSTALLED COST - 1800 feet

Structure Type	Structure & Foundation	Insulators & Hardware	Shield Wire	Phase Conductors	Structure Grounding	Misc. Items	R-O-W Clearing	Access Roads	Gates Culverts	Direct Cost for 1800'	Survey, Eng. CM @ 25%	Contingency @ 20%	Total for 1[illegible]'
Single Pole w/Crossarms	70,000	16,400	1,500	32,500	2,000	2,000	5,000	10,000	1,000	140,400	35,100	35,100	210,[illegible]

Notes:

1. The cost estimate does not include the following items: Cost of Right-Of-Way, Cost of obtaining the Right-Of-Way, Cost of Licensing, Owner's Administration Cost, Interest During Construction, and Construction Mobilization and Demobilization Costs.
2. No cost is included for any rock removal.
3. No cost is included for removal, testing, or disposal of any hazardous materials encountered during excavation.
4. Miscellaneous materials include structure marking and signs, and at selected locations some select backfill.
5. The steel termination structures at both substations is furnished and installed by others.

Client: Fitchburg Gas and Electric | By: PEB Date: 04/06/97
Subject: Estimated Cost for a Double Circuit 69 kV Transmission Line | Chk'd: AD

Assumptions:

a) Voltage - 69 kV
b) Number of circuits - two
c) No structures are located in wetlands
d) Typical soil is dry and granular
e) No special structures are required
f) Transmission line routing is angular
g) Digging is easy to moderately difficult
h) The structures are steel pole with concrete caisson foundations
i) Surveying is 6% of direct cost
j) Engineering is 6% of direct cost
k) Construction Management is 6% of direct cost
l) Contingency is 15 %

ASSUMED LINE PARAMETERS

Structure Type	Type of Terrain	Height Above Ground	Foundation Type: Suspension Structure	Foundation Type: Angle Structure	Number of Poles: Suspension Structure	Number of Poles: Angle Structure	Conductors Per Circuit	Shield Wires Per Circuit	Structures Per Mile: Suspension Structure	Structures Per Mile: Angle Structure	Right-of-Way Width Feet	Normal Loading MVA
Single Pole Davit Arm	Moderately Flat	80	Direct Bury	Caisson	1-Steel	1-Steel	3-556.5 Kcmil	1- 3/8" Steel	10	2	60	60

ESTIMATED INSTALLED COST PER MILE IN 1996 DOLLARS

Structure Type	Structure & Foundation	Insulators & Hardware	Shield Wire	Phase Conductors	Structure Grounding	Misc. Items	R-O-W Clearing	Access Roads	Gates Culverts	Direct Cost Per Mile	Survey, Eng. CM @ 18%	Contingency @ 15%	Total Per Mile
Single Pole Davit Arm	249,800	132,500	4,300	89,900	7,000	2,000	11,600	10,000	500	507,600	91,400	89,900	688,900

Notes:

1. The cost estimate does not include the following items: Cost of Right-Of-Way, Cost of obtaining the Right-Of-Way, Cost of Licensing, Owner's Administration Cost, Interest During Construction, and Construction Mobilization and Demobilization Costs.
2. No cost is included for any rock removal.
3. No cost is included for removal, testing, or disposal of any hazardous materials encountered during excavation.
4. Miscellaneous materials include structure marking and signs, and dampers at selected locations, and some select backfill.
5. The steel termination structures at one substations is furnished and installed by others.
6. The Right-Of-Way is not based on any electromagnetic field limits and is intended for use in estimating a cost for a right-of-way only.
7. The total length of the line, and the total amount of material purchased will impact the overall cost.

CLIENT: FITCHBURG GAS AND ELECTRIC	Date: 04/04/97
SUBJECT: 69 kV Double Circuit Transmission Lines	By: PEB
FILE: FG&EEST1.WK4	Chk'd: AD

COST ESTIMATE FOR OVERHEAD POWER TRANSMISSION LINES

Line Description	Assumptions and Notes:
Voltage - 69 kV	
Rating Per Circuit - 30 MVA, Even Loading	1. No cost is included for the Termination Structures at either end of the line.
Length of Section - 2,600 feet	2. The right-of-way will be provided by FG&E.
Number of Conductors Per Phase - 1	3. The cost estimate does not include the following items: Cost of right-of-way,
Conductor Size, 556.5 kCmil, ACSR	cost for obtaining right-of-way, and cost of licensing.
Shield Wire- 1- 3/8" EHS	4. No cost included for the removal, testing, or disposal of any hazardous materials
Tower type - Double Circuit Steel Pole	encountered during excavation. No hazardous materials anticipated.
Average Span Length - 438 feet	5. The right-of-way is 60 feet wide, and will be cleared for the full length.
Overall Tower Height - 80-90 feet	6. No cost is included for rock removal.
Foundation Type - Direct Bury and Caisson	7. No archeological sites are assumed along the right-of-way. No cost associated
Insulation - Ball & Socket, Porcelain	with this item is included.
Insulation Configuration, I String	8. The Owner's administration cost and interest during construction are not included.

Description of Structures	Line Angle	Overall Hgt, ft.	Weight, lbs.	Foundation size	Comment
Existing Lattice Structure at River St. Sub					
Str. No. A, Strain Angle	20	80	13,400	5' Dia. x 15 feet	Self Supporting
Str. No. B, Strain Angle	20	80	13,400	5' Dia. x 15 feet	Self Supporting
Str. No. C, Suspension	0	90	4,300	Direct Bury-11'	Light Duty
Str. No. D, Suspension	0	90	4,300	Direct Bury-11'	Light Duty
Str. No. E, Suspension	0	90	4,300	Direct Bury-11'	Light Duty
A-Frame at Wallace Road Sub					

Estimated	Material		Labor		Total M & L
Cost Item	Unit	Total	Unit	Total	
Steel Poles, units = lbs.					
Strs. A & B	1.05	28,000	0.50	20,000	48,000
Strs. C , D & E	1.05	14,000	0.50	13,000	27,000
Foundations, units = feet					
Strs. A & B			800	24,000	24,000
Strs. C , D, E			250	8,000	8,000
Hardware & Insulator, units = each str.					
Suspension - 3 Total	1,000	3,000	1,000	3,000	6,000
Strain Angle - 2 Total	3,000	6,000	2,000	4,000	10,000
Conductors, units = feet	0.90	18,000	2.53	39,000	57,000
Shield Wire, units = feet	0.40	1,000	0.76	2,000	3,000
Grounding & Signs, units = each	200	1,200	200	1,200	2,400
Clearing ,Testing, Removal, & Clean-up			16,000	8,000	8,000
Access to Structures, units = feet	3.00	7,000	3.00	7,000	14,000
Total Direct		78,200		129,200	207,400
Railroad Flagmen, Traffic Control				3,000	3,000
Contractor's Indirect (8% of Direct)		6,000		10,000	16,000
Total Indirect		6,000		13,000	19,000
Total Direct + Indirect		84,000		142,000	226,000
Surv, Eng, CM, & Permits (25% of Direct)		20,000		32,000	52,000
Contingency (15% of Direct + Indirect)		17,000		28,000	45,000
Totals Surv,Eng,CM, Permits & Contingency		37,000		60,000	97,000
TOTAL ESTIMATED COST		**121,000**		**202,000**	**323,000**

ALUMINUM COMPANY OF AMERICA SAG AND TENSION DATA

Conductor PARAKEET 556.5 Kcmil 24/ 7 Stranding ACSR

AREA= .4938 Sq.In.
Data from Chart No. 1-889
English Units

SPAN= 450.0 Feet Heavy Loading
Creep is NOT a Factor

Design Points					Final		Initial	
TEMP F	ICE In	WIND Psf	K Lb/F	WEIGHT Lb/F	SAG Ft	TENSION Lb	SAG Ft	TENSION Lb
0.	.50	4.00	.30	2.019	13.47	3813.	12.83	4000.*
30.	1.50	2.00	.00	5.262	16.42	8169.	16.42	8169.
60.	.00	6.00	.00	.850	14.05	1539.	13.13	1647.
-20.	.00	.00	.00	.717	11.51	1583.	10.47	1739.
0.	.00	.00	.00	.717	12.15	1499.	11.13	1636.
30.	.00	.00	.00	.717	13.07	1395.	12.08	1508.
60.	.00	.00	.00	.717	13.93	1309.	12.98	1405.
90.	.00	.00	.00	.717	14.71	1240.	13.83	1319.
120.	.00	.00	.00	.717	15.15	1205.	14.64	1246.
176.	.00	.00	.00	.717	15.96	1145.	15.96	1145.
284.	.00	.00	.00	.717	17.41	1051.	17.41	1051.

* Design Condition

V. SUMMARY AND RECOMMENDATION

Of the three alternative schemes investigated, the installation of a new substation at the Sawyer Passway Site has both technical and economic advantages over the other two schemes. It best utilizes existing facilities; it provides strong circuit ties with the Beech Street and Summer Street Substations; it has a clear, level site; it provides a readily available power supply to future site development and at a cost savings of approximately 30% over the alternative schemes. These savings do not include the cost of extending the transmission lines to the Wallace Road site, which total an additional $423,000. It was assumed this extension would be required to supply the future Rindge Road site.

In our opinion, a major drawback to using the Wallace Road location is the unsuitability of the site due to the significant end-to-end elevation changes, the narrowness of the site and the susceptibility to vandalism.

While Scheme 2, the installation of two substations, one at Wallace Road and one at the Sawyer Passway site provides a slightly higher level of reliability, the site vulnerabilities, as well as the additional costs, cannot be justified in our opinion..

Scheme 3, the installation of a new substation at Wallace Road, has the same or greater site problems as Scheme 2, and additionally the strong ties with the Summer Street substation are diminished.

Based on the above, we recommend the installation of a new substation at the Sawyer Passway site in the vicinity of the existing cooling tower (scheduled for demolition) at an estimated cost of $3,300,000.

VI. GROUNDING OF ELECTRIC STATION CIRCUITS

Existing System

Electric Station was originally a generation plant and currently utilizes equipment rated for line-to-line voltage as the system was originally delta connected.

With the addition of two (2) subtransmission ties to Summer Street, a low resistance grounded substation (6.6 ohm transformer neutral resistor), the Electric Station system is considered low resistance when these lines are closed. This enables over current ground protection to be used on the Electric Station feeders and limits ground fault currents to 1200 amps.

Electric Station currently has feeders that supply a secondary network and radial feeders. The secondary network transformers are all delta connected at the primaries. Radial loads also have delta connected primaries. The radial feeders continue on and feed the Nockege Substation.

System Conversion to Effectively Grounded

The objective of the new system is to establish an effectively grounded system. The benefits of an effectively grounded system are: equipment insulation may be graded, arcing grounds are unlikely, double faults are unlikely, lightning protection will be at the highest efficiency and lowest cost, minimum radio influence and can be connected to reactance grounded systems and, with proper attention to relaying, connected to resistance grounded systems.

If the intent of the neutral grounded system is to limit sustained over voltages to 140% of line-to-ground voltages such that grounded-neutral arresters may be used, the system impedance characteristics should be as follows: The ratio of the zero sequence reactance to the positive sequence reactance should be kept below 3 ($X0/X1 < 3$) and the ratio of the zero sequence resistance to the positive sequence reactance should be kept below 1 ($R0/X1 < 1$).

The impedance ratios are important as the ratio limits imply that line-to-ground voltages will not exceed 1.4 times normal value under normal, emergency or faulted conditions. Only when the maximum voltage is limited to 1.4 times normal may the economic benefits of insulation grading and grounded-neutral arresters may be implemented.

To convert the existing system to an effectively grounded system the following is recommended:

1. Change Substation Transformer Connection to Delta primary - Wye solidly grounded.

   In order to lower the X0/X1 and R0/X1 values the transformer connection must be changed from Wye-Delta to Delta-Wye. Below is a comparison of the two winding configurations in the same operating scenario. This is to illustrate the effect of the change in the winding configuration. (Refer to Item 5, Follow Up Work)

   The existing source impedance at Electric Station with Wye-Delta Transformer is:

R1	X1	R0	X0	X0/X1	R0/X1
0.048	0.637	22.9	1.51	2.37	35.9

   Due to the excessive R0/X1 value the existing system is not considered to be effectively grounded.

   The new source impedance at the proposed new Sawyer Passway substation with a Delta-Wye transformer is:

R1	X1	R0	X0	X0/X1	R0/X1
0.055	0.675	0.077	0.801	1.19	0.114

   The ratios have been reduced to the levels required to be classified as an effectively grounded system.

2. Underground Cable

A. Paper Insulated Lead Covered (PILC) Cable

Underground PILC cable utilizes a lead sheath in which may be used for neutral return and fault currents. Based on the information supplied by FG&E i.e., all splices in all manholes are bonded and grounded indicates that the sheath is used for return and fault currents. This is ideal for an effectively grounded system and this practice should continue. The lead sheath surrounds the conductor in its entirety and is continuous in its length. Therefore, should a line-to-ground fault occur, the conductor bolts to the sheath and the sheath carries the fault current to the first ground/earthing point. After this point, both the earth and the sheath carry the fault current back to the substation or source.

B. Underground EPR Cable

Unlike PILC cable EPR cable does not have a sheath. However, the cable has a one-third flat copper strap neutral surrounding each phase. This strap is used for carrying neutral currents and fault currents. Similar to the PILC lead sheath the flat copper strap should be bonded at every splice at every manhole.

C. Separate Underground Neutral Conductor

Duct banks from Electric Station presently have a separate bare copper conductor that is bonded to all PILC sheaths and grounded in each manhole. Due to the addition of single phase loads and the anticipated increase in ground fault current we recommend that this practice continue.

To ensure neutral and ground conductor continuity, we recommend that a new 4/0 AWG bare copper conductor be installed between the proposed new Sawyer Passway Substation and Nockege Substation and bonded to the existing grounding conductor in the manhole and duct bank system..

In areas where the condition of the neutral conductor is in question we recommend that it be repaired or replaced prior to the change from a resistance system to a solidly grounded system. It is imperative that the neutral system be in the best condition possible prior to the change due to the increase in neutral and ground fault currents. This is especially important for all subtransmission cables to ensure a low resistance path exists for neutral and ground fault currents.

3. Overhead Construction

Based upon the construction standards submitted, Hendrix and 8-Pin cross arm construction with a common neutral to primary and secondary circuits utilizing 336 ACSR phase conductors and 1/0 AWG ACSR neutral conductors appear to be adequate.

The neutral is to be grounded by ground rod at all equipment locations and bonded to the cable sheath and neutral at all riser locations. A minimum of four (4) ground rods per circuit mile should be installed.

4. Ground Over Current Protection

Ground over current protection must be installed to isolate subtransmission and faulted distribution circuits to limit equipment damage and minimize the number of customers effected by the outage.

Ground over current protection may be limited due to load imbalances between the phases. The relay may reach 80 to 90 percent into the circuit length that it is protecting. However, as the reach increases, the sensitivity to unbalanced loads also increase and false tripping could result.

The daily circuit load sheets provided to us by FG&E indicate that, were there are single phase loads, the circuits appear to be well balanced. When undertaking contingency planning, the balance of a section of transferred load must be taken into consideration to ensure that the neutral current does not exceed the relay setting.

5. Follow Up Work

A. During the follow up design phase a study should be undertaken to identify the following:

1. System Electrical Short Circuit Study

The study should include modeling of the 69kV, the proposed new Sawyer Passway Station, Summer Street and the distribution circuits to ensure that voltages at any point in the distribution system will not exceed 1.4 times normal line-to-ground voltages for any operating condition.

The study will determine the optimum impedance of the new Delta-Wye transformer, identify abnormal operating conditions and make recommendations to eliminate the condition, determine the adequacy of new and existing breaker ratings at the proposed Sawyer Passway and Summer Street Substations.

2. Summer Street Station

Summer Street Station is currently resistance grounded through a 6.6 ohm resistor and its ground fault protection set on this basis. At a minimum this station's relaying should be addressed to ensure that the relay and its settings are adequate when the subtransmission feeders 3A and 9 are tied to the new effectively grounded system.

VII. REVIEW OF ELECTRIC STATION NETWORK FEEDERS 8,10A AND 11

While feeders 8, 10A and 11 emanating from the Electric Station all supply network transformers, at present, only Feeder 10A supplies pure network loads. Feeder 10A is supplied by Feeder 10-113 which bifurcates into Feeders 10A and 10B; 10B supplies radial load. A total of 2500 KVA of network transformers is connected to Feeder 10A and approximately 1200 KVA of radial load to Feeder 10B. The maximum demand on Feeder 10-113 has been approximately 1200 KVA.

Feeder 11 supplies 2700 KVA of network transformers and is also the primary source of supply to the General Electric Company which has 6000 KVA of transformer capacity and a demand of approximately 2500 KVA. Feeder 11 also supplies a 300 KVA transformer at the library. According to FG&E personnel, this load could be supplied directly from the 120/208 volt secondary network system. We recommend that this transfer to the secondary network be carried out. The maximum demand on Feeder 11 has been approximately 3300 KVA.

The majority of the loads on Feeder 8 are radially supplied. The location of these loads and the installed transformer capacities are as follows:

Location	Transformer KVA
Micron Products	750
Hotel Raymond	300
Century Plastics	1,000
Sentinel	500
Day Street Elderly	750
Post Office	1,000
Workers Credit	500
District Court	225
City Hall	300
TOTAL:	5,325 KVA

In addition to these loads, there are 6-300 KVA and 1- 500 KVA (total 2300 KVA) network transformers supplied by Feeder 8. The maximum demand on Feeder 8 has been approximately 2900 KVA.

Based on the above, we recommend that the following circuit reconfigurations be incorporated.

The 2300 KVA of network transformers presently on Feeder 8 should be transferred to Feeders 10A and 11 leaving Feeder 8 to supply radial loads only. To provide better load balance, the majority of the transformers should be placed on Feeder 10A. Feeder 8 would remain as a backup feeder to the Wallace Road Substation. Removing the network loads from this feeder will eliminate potential problems to the network loads whenever Feeder 8 is used to backup the Wallace Road Substation.

In order to accomplish this load transfer, it will be necessary to extend the 10A and/or 11 Feeders to pick up the last network transformers presently supplied by Feeder 8. Assuming there are adequate spare ducts, the estimated cost for extending these feeders (a distance of approximately 1500 feet) is $45,000.

In addition to the above, we would also recommend that to help compensate for this transfer of load from Feeder 8 to Feeders 10A and 11, the Feeder 10B load also be transferred to Feeder 8. Feeder 10-113 will then become a pure network feeder.

Since network feeders 10-113 and 11 must each be capable of carrying the load of both feeders, as the network loads grow, we would recommend that the General Electric Company load be transferred to Feeder 10 as its primary supply. Feeder 17 can remain as a backup via the automatic transfer scheme. The existing Feeder 10 load can be reduced by transferring its load to the Beech Street Substation or converting the 4kV load at Nockege (Circuit 22, 23 & 24) to 13.8kV.

VIII. MODIFICATIONS TO THE 69 KV TRANSMISSION SYSTEM

As part of our investigation, we reviewed the various studies that have been done on the FG&E system with respect to a new system supply point, as well as possible extension to the 69kV transmission system. Regarding a new supply point, our review supports the studies which recommend the Lunenburg/Townsend areas as the preferred location. By establishing a new 115kV to 69kV supply point at this location, the contingency of the Flagg Pond to Pratts Junction double circuit line outage would be mitigated. In addition to this improved reliability, a second supply point would improve voltages and reduce losses. However, the recent change out of the two Flagg Pond transformers will likely delay the need for a new supply point well into the future.

While our recommendation for a new substation at the Sawyer Passway site eliminates the need for a new substation at Wallace Road, it supports the need for a future 69kV/13.8kV substation at the existing Rindge Road location.

How this station would be supplied is dependent upon whether a new substation is installed at Wallace Road and whether or not this route is intended to become part of a 69kV double circuit loop for the FG&E system. We have put some cost estimates together based on the premise that this would be part of a future double circuit loop. Detailed cost estimates are included at the end of Section 4.

The estimated cost for extending the existing double circuit steel pole, 69kV transmission line from the River Street Substation to the Wallace Road site is $323,000 excluding the terminal structures. The distance is approximately 0.5 mile. The estimated cost for continuing on with this double circuit configuration to the Rindge Road site, a distance of approximately 3 miles, is $2,100,000, again excluding the terminal structures. FG&E owns the required right-of-way between the River Street Substation and the Rindge Road site. At present, there is a single circuit 13.8kV line (Feeder 41) installed on single circuit structures, with 1/0 ASR conductors, between Wallace Road and Rindge Road, which is insulated and suitable for 69kV operation.

Assuming a new substation is not installed at the Wallace Road site, there would be no need to install 69kV switching facilities at this location either. The double circuit 69kV lines would be express from the River Street Substation to the Rindge Road location.

We have also estimated the cost for a second 69kV transmission line between the Summer Street Substation and the Sawyer Passway site. We have provided this estimate for information only, since it does not play a part in any of our recommendations. It may prove beneficial if the site is developed for cogeneration facilities or by an IPP. Since one of the existing 13.8 kV lines between the Electric Station and the Summer Street Substation is presently installed on the 69kV double circuit structures, the 13.8kV line would have to be relocated or underbuilt on these structures. The estimated cost for this single circuit 69kV line extension is $211,000.

IX. IMPACT IF SAWYER PASSWAY SITE IS DEVELOPED AS COGENERATION SITE OR BY AN IPP

Should the Sawyer Passway location be developed as an IPP site, the installation of additional transmission lines may be required. The voltage and ampacity requirements would be dependent upon the amount of generation at the site.

The existing right-of-way between the Summer Street Substation and the Electric Station could readily accommodate double circuit 69kV transmission structures. In fact, there are two steel crossing towers on the right-of-way which are presently configured for double circuits. However, unless the site is developed as an IPP site or by a customer with a significant power requirement, the existing single 69kV transmission line is adequate. We recommend that the existing backup between the future proposed Sawyer Passway site and Summer Street Substation remain as it is via the two 13.8kV feeders 3A and 9.

EXHIBIT B

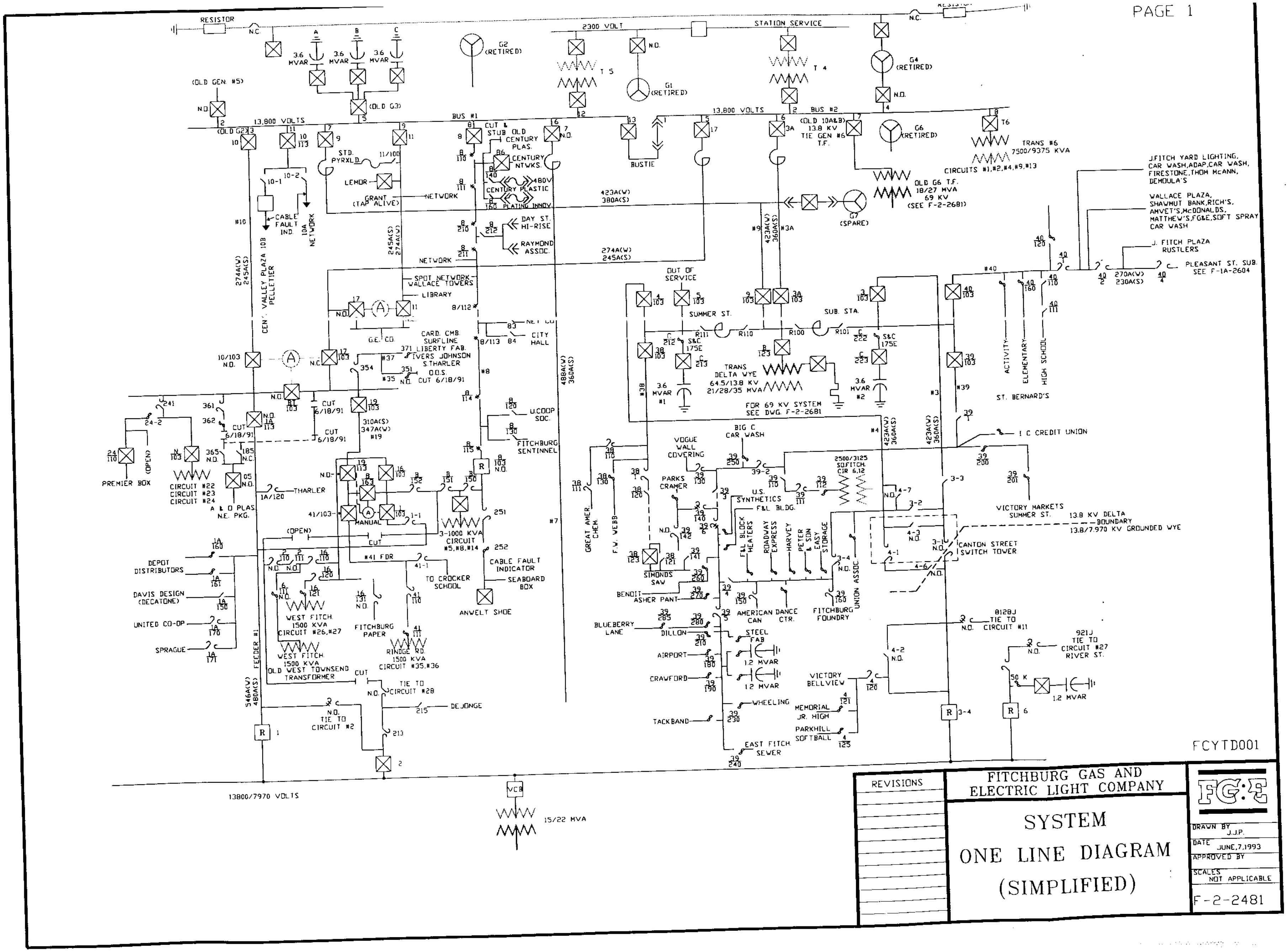
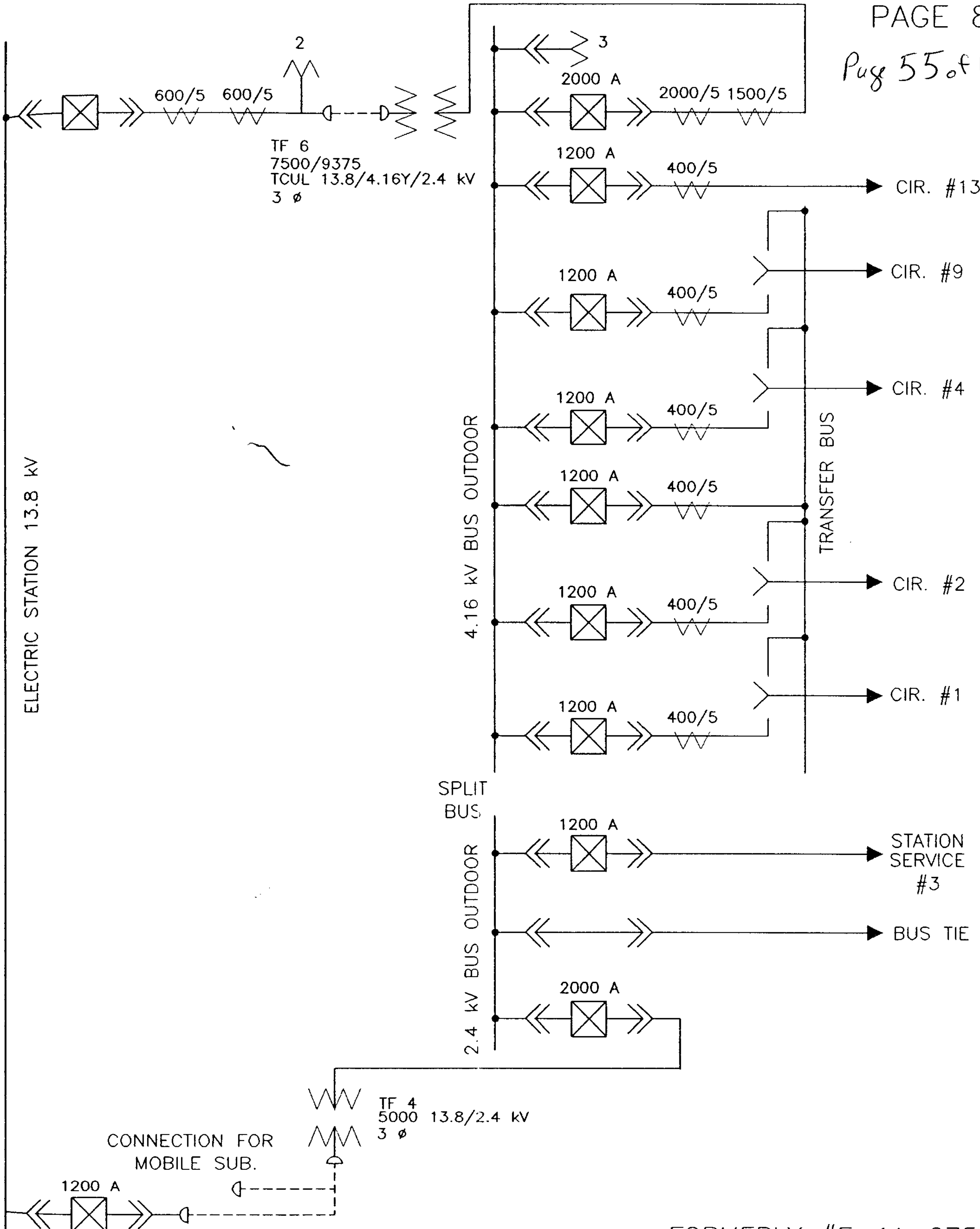

PAGE 1
FITCHBURG GAS AND ELECTRIC LIGHT COMPANY
SYSTEM
ONE LINE DIAGRAM
(SIMPLIFIED)
FG&E
DRAWN BY J.J.P.
DATE JUNE,7,1993
APPROVED BY
SCALES NOT APPLICABLE
F-2-2481
REVISIONS
FCYTD001
13,800 VOLTS
2300 VOLT
STATION SERVICE
BUS #1
BUS #2
13800/7970 VOLTS
CANTON STREET SWITCH TOWER
FOR 69 KV SYSTEM SEE DWG F-2-2681

EXHIBIT C



FORMERLY #F-1A-2755

REV.	DESCRIPTION	BY	DATE	CHK	APR
A	GENERAL UPDATE	EMS	5/5/97	MAF	CEC

REVISIONS

DRAWN: ems

CHECKED: MAF

APPROVED: CEC

Unitil
Unitil Service Corp.

Fitchburg Gas and Electric Light Company

ELECTRIC STATION #2
ONE-LINE DIAGRAM
64.5-13.8Y/7.97 kV

SCALE	DATE	SHEET	DRAWING NO.
N/A	7/7/69	1 OF 1	FAS02D1

EXHIBIT D

Gas and Electric Light Company | Growth Rate
Electric Distribution Circuit Load Projections | 2%

Note: Values taken from 1997 Distribution Circuit Load Projections Developed by P.Bradshaw.

LOCATION	PEAK RATING	1991 PK	1992 PK	1993 PK	1994 PK	1995 PK	1996 PK	1997 PK	1998 PK	1999 PK	2000 PK	2001 PK	2002 PK	2003 PK	2004 PK	2005 PK	2006 PK	2007 PK	2008 PK	2009 PK	2010 PK	2011 PK	2012 PK	2013 PK
BEECH ST.69 KV																								
#1Transformer 13.8	25830	11872	16320	15360	14208	15936	15552	12238	13386	10937	12049	12290	12536	12787	13042	13303	13569	13841	14118	14400	14688	14982	15281	15587
#1 Feeder	11200	6080	6016	5888	6208	6208	6272	5952	3378	4531	5727	5842	5958	6077	6199	6323	6449	6578	6710	6844	6981	7120	7263	7408
#2 Feeder	10200	0	640	0	704	1600	1600	1147	1339	4180	4264	4349	4436	4525	4615	4708	4802	4898	4996	5096	5197	5301	5407	5516
#3-4 Feeder	8400	3520	5312	4160	5684	4800	4288	2040	2422	4550	5342	5449	5558	5669	5024	5125	5227	5332	5438	5547	5658	5771	5887	6004
#6 Feeder	10200	5632	6272	4992	5440	7104	7680	5609	5163	266	272	277	283	289	294	300	306	312	319	325	332	338	345	352
#7 Feeder	11700													0	0									
CANTON ST. 4 KV	3510	1656	1176	1200	1248	1248	1248	1225	1225	1324	1351	1378	1405	1433	1462	1491	1521	1551	1582	1614	1646	1679	1713	1747
Circuit #10	1450	1152	1008	504	504	504	576	588	576	1312	1338	1365	1392	1420	1449	1478	1507	1537	1568	1599	1631	1664	1697	1731
Circuit #11	2000	729	972	792	828	828	846	847	829	898	916	934	953	972	991	1011	1032	1052	1073	1095	1117	1139	1162	1185
CANTON ST. 13.8	14000	4656	5424	4992	5184	5376	5088	5306	5211	5399	5507	5618	5730	5845	5961	6081	6202	6326	6453	6582	6714	6848	6985	7125
Circuit #11	11400	4600	5360	4960	5120	5320	5280	4980	4980	5603	5715	5830	5946	6065	6186	6310	6436	6565	6696	6830	6967	7106	7248	7393
ELECTRIC STA.														0	0									
#6 Gen.T.F.TIE	29130	13440	12240	14400	16800	12480	12720	12143	16684	14026	14306	14592	14884	15182	15485	15795	16111	16433	16762	17097	17439	17788	18144	18506
#8 Feeder	6600	3120	2737	3720	3720	2880	2520	2964	3179	3246	3311	3377	3445	3514	3584	3656	3729	3804	3880	3957	4036	4117	4199	4283
#10 Feeder	6600	4680	4560	3840	3360	3120	3840	3299	3370	4075	4157	4240	4324	4410	4499	4589	4680	4774	4870	4967	5066	5168	5271	5376
#10-113	3100	2640	1560	2400	2160	1440	1200	1458	1147	1273	1299	1325	1351	1378	1406	1434	1462	1492	1521	1552	1583	1615	1647	1680
#11 Feeder	6600	4440	3689	4800	3360	3120	3240	3036	2438	3626	3698	3772	3848	3925	4003	4084	4165	4249	4333	4420	4509	4599	4691	4785
#17 Feeder	6600	3840	240	240	3120	2880	3000	3442	359	3184	3247	3312	3378	3446	3514	3585	3656	3730	3804	3880	3958	4037	4118	4200
#6 Distr.T.F.	9400	6048	5760	5760	5724	5688	5256	4804	4746	5578	5689	5803	5919	6037	6158	6281	6407	6535	6666	6799	6935	7074	7215	7360
#1 CKT	2200	1260	1260	1224	1368	1260	1296	865	937	1375	0	0	0	0	0	0	0	0	0	0	0	0	0	0
#2 CKT	2200	1332	1332	1260	1368	1044	612	1261	1604	649	0	0	0	0	0	0	0	0	0	0	0	0	0	0
#4 CKT	2200	1512	1224	1368	1440	2088	1944	1511	1528	1559	0	0	0	0	0	0	0	0	0	0	0	0	0	0
#9 CKT (8A)	2200	1548	1260	1332	1404	1269	1332	925	987	1414	1442	1471	1500	1530	1561	1592	1624	1656	1689	1723	1757	1793	1828	1865
#13 CKT (8A)	2200	1584	1656	1512	1584	1728	1440	1191	1146	1528	1559	1590	1622	1654	1688	1721	1756	1791	1827	1863	1900	1938	1977	2017
FLAGG PD.#1 T.F.	100000							34747																
FLAGG PD.#2 T.F.	100000							32224																
LUN.SUB. 13.8 KV	13180	4320	4560	5808	5760	6000	5568	6119	6406	6879	7017	7157	7300	7446	7595	7747	7902	8060	8221	8385	8553	8724	8899	9077
Circuit #30	9561	4256	3584	4864	4736	4800	4416	4717	5227	5657	5770	5885	6003	6123	6246	6370	6498	6628	6760	6896	7033	7174	7318	7464
Circuit #31	9600	1280	976	3584	1072	1200	1152	1280	1084	1223	1247	1272	1297	1323	1349	1376	1404	1432	1461	1490	1520	1550	1581	1613
NOCKEGE SUB		3370	3456	2909	2534	2536	2534	2738	2709	2862	2919	2977	3037	3098	3160	3223	3287	3353	3420	3489	3558	3629	3702	3776
Breaker Trans.	5000	0	3082	0	0	0	0																	
Circuit #22	2200	2030	1987	1598	1138	1238	1224	1124	1225	1299	1325	1351	1378	1406	1434	1462	1492	1521	1552	1583	1615	1647	1680	1713
Circuit #23	2200	835	1238	979	850	1094	864	865	879	917	935	954	973	992	1012	1033	1053	1074	1096	1118	1140	1163	1186	1210
Circuit #24	2200	1181	1210	1195	1210	1124	1267	1268	1326	1573	1605	1637	1669	1702	1736	1771	1807	1843	1880	1917	1955	1995	2035	2075
PLEASANT ST.4KV	3125	882	708	348	708	456	528	793	817	560	572	583	595	607	619	631	644	657	670	683	697	711	725	740
Circuit #34	1450	882	720	876	960	1008	972	1045	1105	1031	2642	2695	2749	2804	2860	2917	2975	3035	3096	3157	3221	3285	3351	3418
PLEASANT 13KV	14000	6912	7200	7776	9216	9984	9696	9179	9370	10289	10495	10705	10919	11137	11360	11587	11819	12055	12297	12542	12793	13049	13310	13576
Circuit #37	11400	5184	5376	5696	7040	7296	5568	5679	5793	5909	6027	6148	6270	6395	6523	6654	6787	6923	7061	7202	7346	7493	7643	7796
Circuit #38	11400	3328	3200	4160	3648	7424	7168	7394	7458	7607	7795	7914	8072	8233	8398	8566	8737	8912	9090	9272	9458	9647	9840	10037
PRINCETON RD.																								
Transformer #1	10500						11381	10685	11147	12234	12478	12728	12982	13242	13506	13777	14052	14333	14620	14912	15210	15515	15825	16141
Circuit 56/103	7000						7803	3737	3673	9003	9503	10003	10503	10713	10927	11146	11369	11596	11828	12065	12306	12552	12803	13059
Circuit 55/103	7000						3682	7157	7944	3907	3986	4065	4147	4230	4315	4401	4489	4579	4670	4764	4859	4956	5055	5156
Transformer #2	20000						3949	3060	5633	21848	22285	22731	23186	23650	24123	24605	25097	25599	26111	26633	27166	27709	28264	28829
Circuit 54/103	21500						262	693	5127	273	278	284	289	295	301	307	313	319	325	332	339	345	352	359
Circuit 53/103	21500						10500	3091	1179	11143	11366	11593	11825	12062	12303	12549	12800	13056	13317	13583	13855	14132	14415	14703
Circuit 51/103	21500						10500	900	6374	11143	11366	11593	11825	12062	12303	12549	12800	13056	13317	13583	13855	14132	14415	14703
BT/103	21500																							
RINDGE RD. 4KV	1730	1267	1440	1056	1176	1392	1248	1249	1369	1396	1424	1453	1482	1511	1542	1573	1604	1636	1669	1702	1736	1771	1806	1842
Circuit #35	1500	576	576	605	624	614	499	538	557	530	540	551	562	573	585	596	608	620	633	646	658	672	685	699
Circuit #36	1500	826	826	893	902	902	922	874	970	989	1009	1029	1050	1071	1092	1114	1137	1159	1182	1206	1230	1255	1280	1305
RIVER ST.	16830	8325	8325	8325	8925	10725	11775	11952	12270	13117	13379	13647	13920	14198	14482	14772	15067	15369	15676	15990	16309	16636	16968	17308
FitchburgPaperCo.	9600	3920	4320	4566	4560	4880	5000	5418	6533	6120	6242	6367	6495	6625	6757	6893	7030	7171	7314	7461	7610	7762	7917	8076
Circuit #27	8400	4864	4672	4544	2816	4800	2752	2996	2231	2920	2979	3038	3099	3161	3224	3289	3354	3422	3490	3560	3631	3704	3778	3853
Circuit #28	9600	0	0	0	4672	6400	7680	6948	5864	8150	8313	8479	8649	8822	8998	9178	9362	9549	9740	9935	10134	10336	10543	10754
S.FITCH 4KV	3125	1584	1526	1325	1354	1411	1411	1268	1441	1468	1497	1527	1558	1589	1621	1653	1686	1720	1755	1790	1825	1862	1899	1937
Circuit #6	1450	1123	1094	912	835	970	1104	845	836	1172	1195	1219	1243	1268	1293	1319	1345	1372	1400	1428	1456	1486	1515	1546
Circuit #12	1450	442	413	470	461	461	576	519	615	611	623	636	649	662	675	689	702	717	731	745	760	776	791	807
SUMMER ST.13.8	38530	15680	15680	14089	14726	15040	14080	15212	15517	15827	16144	16466	16796	17132	17475	17824	18181	18544	18915	19293	19679	20073	20474	20884
#3/103	8400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
#3A/103	14400	7008	6912	9702	6624	6912	6720	6310	6502	7131	7274	7419	7568	7719	7874	8031	8192	8356	8523	8693	8867	9044	9225	9410
#4/103	8400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
#5/103	6480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
#9/103	14400	5376	5376	5376	8064	5760	5280	5386	5493	5603	5715	5330	5946	6065	6186	6310	6436	6565	6696	6830	6967	7106	7248	7393
#38/103	10200	2535	2400	2456	2616	2604	2748	3662	3735	3810	3866	3964	5946	6065	6186	6310	6436	6565	6696	6830	6967	7106	7248	7393
#39/103	10200	4000	4000	4146	4440	4560	3720	3904	9260	9445	9634	9827	10023	10223	10428	10636	10849	11066	11288	11513	11744	11978	12218	12462
#40/103	9200	3200	3120	3120	3120	3040	3040	2550	3163	3226	3291	3356	3424	3492	3562	3634	3706	3780	3856	3933	4012	4092	4174	4257
#01/103	84000		Transmission Line																					
#02/103	64000		Transmission Line																					

LOCATION	PEAK RATING	1991 PK	1992 PK	1993 PK	1994 PK	1995 PK	1996 PK	1997 PK	1998 PK	1999 PK	2000 PK	2001 PK	2002 PK	2003 PK	2004 PK	2005 PK	2006 PK	2007 PK	2008 PK	2009 PK	2010 PK	2011 PK	2012 PK	2013 PK
#08/103	27500		Transmission Line																					
#09/103	27500		Transmission Line																					
TOWNS. 10.5 MVA	12020	**7872**	**8208**	**7776**	**8208**	**10171**	**10176**	**9752**	**10587**	**10799**	**11015**	**11235**	**11460**	**11689**	**11923**	**12161**	**12405**	**12653**	**12906**	**13164**	**13427**	**13696**	**13970**	**14249**
Circuit #15 Alcon	4800	2985	3334	3179	4282	4240	4737	0	0	5027	5127	5230	53235	54300	55386	56493	57623	58776	59951	61150	62373	63621	64893	66191
Circuit #16 Harbor	5300	2752	3008	2784	2768	3680	3616	4398	4079	3837	3914	3992	4072	4153	4237	4321	4408	4496	4586	4677	4771	4866	4964	5063
Circuit #17 Center	5300	2640	2320	2352	2304	3456	2688	2645	3506	2853	2910	2968	3072	3133	3196	3260	3325	3392	3460	3529	3599	3671	3745	3820
Circuit #17A	5300	0	0	0	0	2752	0	2645	0	0	0	0												
WALLACE RD.SUB	3000			**Removed**																				
Circuit #41																								
Circuit #5	2200	**Transferred to Ckt. 26 W. Fitchburg**																						
Circuit #8	1450	**Transferred to Ckt. 24 Nockege**																						
Circuit #14	2200	**Transferred to Feeder 1 Beech St.**																						
WEST FITCH.SUB	1750	**720**	**696**	**768**	**804**	**696**	**756**	**732**	**865**	**802**	**818**	**835**	**851**	**868**	**885**	**903**	**921**	**940**	**958**	**978**	**997**	**1017**	**1037**	**1058**
Circuit #26	1450	9998	1008	1104	1067	1046	1094	1046	1114	1161	1184	1208	1232	1257	1282	1307	1334	1360	1387	1415	1443	1472	1502	1532
Circuit #27	1450	0	0	0	0	0	0	0	942	0	0	0												
W.TOWNSEND	5125	**3456**	**3392**	**34556**	**6882**	**4288**	**3712**	**3616**	**3761**	**3939**	**4018**	**4098**	**4180**	**4264**	**4349**	**4436**	**4525**	**4615**	**4707**	**4802**	**4898**	**4995**	**5095**	**5197**
Circuit#18(W.Towns)	5300	1632	1680	1664	1920	1766	1828	1848	1944	1940	1979	2018	2059	2100	2142	2185	2229	2273	2319	2365	2412	2461	2510	2560
Circuit #19 (Ashby)	5300	2000	1952	2016	2032	2192	2144	1968	2263	2275	2321	2367	2414	2462	2512	2562	2613	2665	2719	2773	2828	2885	2943	3002

EXHIBIT E

Loading in Per Unit of Rating

LOCATION	PEAK RATING	1991 PK	1992 PK	1993 PK	1994 PK	1995 PK	1996 PK	1997 PK	1998 PK	1999 PK	2000 PK	2001 PK	2002 PK	2003 PK	2004 PK	2005 PK	2006 PK	2007 PK	2008 PK	2009 PK	2010 PK	2011 PK	2012 PK	2013 PK
																0	9150	0	8540	10065	12200	10065	9150	10065
BEECH ST.69 KV																								
#1Transformer 13.8	25830	0.460	0.632	0.595	0.550	0.617	0.602	0.474	0.518	0.423	0.466	0.476	0.485	0.495	0.505	0.515	0.525	0.536	0.547	0.557	0.569	0.580	0.592	0.603
#1 Feeder	11200	0.543	0.537	0.526	0.554	0.554	0.560	0.531	0.302	0.405	0.511	0.522	0.532	0.543	0.553	0.565	0.576	0.587	0.599	0.611	0.623	0.636	0.648	0.661
#2 Feeder	10200	0.000	0.063	0.000	0.069	0.157	0.157	0.112	0.131	0.410	0.418	0.426	0.435	0.444	0.452	0.462	0.471	0.480	0.490	0.500	0.510	0.520	0.530	0.541
#3-4 Feeder	8400	0.419	0.632	0.495	0.677	0.571	0.510	0.243	0.288	0.542	0.636	0.649	0.662	0.675	0.598	0.610	0.622	0.635	0.647	0.660	0.674	0.687	0.701	0.715
#6 Feeder	10200	0.552	0.615	0.489	0.533	0.696	0.753	0.550	0.506	0.026	0.027	0.027	0.028	0.028	0.029	0.029	0.030	0.031	0.031	0.032	0.033	0.033	0.034	0.034
#7 Feeder	11700	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CANTON ST. 4 KV	3510	0.472	0.335	0.342	0.356	0.356	0.356	0.349	0.349	0.377	0.385	0.393	0.400	0.408	0.416	0.425	0.433	0.442	0.451	0.460	0.469	0.478	0.488	0.498
Circuit #10	1450	0.794	0.695	0.348	0.348	0.348	0.397	0.406	0.397	0.905	0.923	0.941	0.960	0.979	0.999	1.019	1.039	1.060	1.081	1.103	1.125	1.148	1.170	1.194
Circuit #11	2000	0.365	0.486	0.396	0.414	0.414	0.423	0.424	0.415	0.449	0.458	0.467	0.476	0.486	0.496	0.506	0.516	0.526	0.537	0.547	0.558	0.569	0.581	0.592
CANTON ST. 13.8	16830	0.333	0.387	0.357	0.370	0.384	0.363	0.379	0.372	0.386	0.393	0.401	0.409	0.417	0.426	0.434	0.443	0.452	0.461	0.470	0.480	0.489	0.499	0.509
Circuit #11	11400	0.404	0.470	0.435	0.449	0.467	0.463	0.437	0.437	0.491	0.501	0.511	0.522	0.532	0.543	0.554	0.565	0.576	0.587	0.599	0.611	0.623	0.636	0.649
ELECTRIC STA.																								
#6 Gen.T.F.TIE	29130	0.461	0.420	0.494	0.577	0.428	0.437	0.417	0.573	0.481	0.491	0.501	0.511	0.521	0.532	0.542	0.553	0.564	0.575	0.587	0.599	0.611	0.623	0.635
#8 Feeder	6600	0.473	0.415	0.564	0.564	0.436	0.382	0.449	0.482	0.492	0.502	0.512	0.522	0.532	0.543	0.554	0.565	0.576	0.588	0.600	0.612	0.624	0.636	0.649
#10 Feeder	6600	0.709	0.691	0.582	0.509	0.473	0.582	0.500	0.511	0.617	0.630	0.642	0.655	0.668	0.682	0.695	0.709	0.723	0.738	0.753	0.768	0.783	0.799	0.815
#10-113	3100	0.852	0.503	0.774	0.697	0.465	0.387	0.470	0.370	0.411	0.419	0.427	0.436	0.445	0.453	0.462	0.472	0.481	0.491	0.501	0.511	0.521	0.531	0.542
#11 Feeder	6600	0.673	0.559	0.727	0.509	0.473	0.491	0.460	0.369	0.549	0.560	0.572	0.583	0.595	0.607	0.619	0.631	0.644	0.657	0.670	0.683	0.697	0.711	0.725
#17 Feeder	6600	0.582	0.036	0.036	0.473	0.436	0.455	0.522	0.054	0.482	0.492	0.502	0.512	0.522	0.532	0.543	0.554	0.565	0.576	0.588	0.600	0.612	0.624	0.636
#6 Distr.T.F.	9400	0.643	0.613	0.613	0.609	0.605	0.559	0.511	0.505	0.593	0.605	0.617	0.630	0.642	0.655	0.668	0.682	0.695	0.709	0.723	0.738	0.753	0.768	0.783
#1 CKT	2200	0.573	0.573	0.556	0.622	0.573	0.589	0.393	0.426	0.625	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
#2 CKT	2200	0.605	0.605	0.573	0.622	0.475	0.278	0.573	0.729	0.295	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
#4 CKT	2200	0.687	0.556	0.622	0.655	0.949	0.884	0.687	0.695	0.708	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
#9 CKT	2200	0.704	0.573	0.605	0.638	0.577	0.605	0.420	0.449	0.643	0.655	0.669	0.682	0.695	0.709	0.724	0.738	0.753	0.768	0.783	0.799	0.815	0.831	0.848
#13 CKT	2200	0.720	0.753	0.687	0.720	0.785	0.655	0.541	0.521	0.695	0.709	0.723	0.737	0.752	0.767	0.782	0.798	0.814	0.830	0.847	0.864	0.881	0.899	0.917
FLAGG PD.#1 T.F.	111400																							
FLAGG PD.#2 T.F.	117230																							
LUN.SUB. 13.8 KV	13180	0.328	0.346	0.441	0.437	0.455	0.422	0.464	0.486	0.522	0.532	0.543	0.554	0.565	0.576	0.588	0.600	0.612	0.624	0.636	0.649	0.662	0 675	0.689
Circuit #30	9600	0.445	0.375	0.509	0.495	0.502	0.462	0.493	0.547	0.592	0.603	0.616	0.628	0.640	0.653	0.666	0.680	0.693	0.707	0.721	0.736	0.750	0.765	0.781
Circuit #31	9600	0.133	0.102	0.373	0.112	0.125	0.120	0.133	0.113	0.127	0.130	0.133	0.135	0.138	0.141	0.143	0.146	0.149	0.152	0.155	0.158	0.161	0.165	0.168
NOCKEGE SUB																								
Breaker Trans.	5000	0.000	0.616	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Circuit #22	2200	0.923	0.903	0.726	0.517	0.563	0.556	0.511	0.557	0.590	0.602	0.614	0.626	0.639	0.652	0.665	0.678	0.692	0.705	0.719	0.734	0.749	0.764	0.779
Circuit #23	2200	0.380	0.563	0.445	0.386	0.497	0.393	0.393	0.400	0.417	0.425	0.434	0.442	0.451	0.460	0.469	0.479	0.488	0.498	0.508	0.518	0.529	0.539	0.550
Circuit #24	2200	0.537	0.550	0.543	0.550	0.511	0.576	0.576	0.603	0.715	0.730	0.744	0.759	0.774	0.789	0.805	0.821	0.838	0.854	0.871	0.889	0.907	0.925	0.943
PLEASANT ST.4KV	3510	0.282	0.227	0.111	0.227	0.146	0.169	0.254	0.261	0.179	0.183	0.187	0.190	0.194	0.198	0.202	0.206	0.210	0.214	0.219	0.223	0.228	0.232	0.237
Circuit #34	1450	0.608	0.497	0.604	0.662	0.695	0.670	0.721	0.762	0.711	1.822	1.859	1.896	1.934	1.972	2.012	2.052	2.093	2.135	2.178	2.221	2.266	2.311	2.357
PLEASANT 13KV	15400	0.494	0.514	0.555	0.658	0.713	0.693	0.656	0.669	0.735	0.750	0.765	0.780	0.796	0.811	0.828	0.844	0.861	0.878	0.896	0.914	0.932	0.951	0.970
Circuit #37	11400	0.455	0.472	0.500	0.618	0.640	0.488	0.498	0.508	0.518	0.529	0.539	0.550	0.561	0.572	0.584	0.595	0.607	0.619	0.632	0.644	0.657	0.670	0.684
Circuit #38	11400	0.292	0.281	0.365	0.320	0.651	0.629	0.649	0.654	0.667	0.684	0.694	0.708	0.722	0.737	0.751	0.766	0.782	0.797	0.813	0.830	0.846	0.863	0.880
PRINCETON RD.																								
Transformer #1	13540	0.000	0.000	0.000	0.000	0.000	1.084	1.018	1.062	1.165	1.188	1.212	1.236	1.261	1.286	1.312	1.338	1.365	1.392	1.420	1.449	1.478	1.507	1.537
Circuit 56/103	10500	0.000	0.000	0.000	0.000	0.000	1.115	0.534	0.525	1.286	1.358	1.429	1.500	1.530	1.561	1.592	1.624	1.657	1.690	1.724	1.758	1.793	1.829	1.866
Circuit 55/103	10500	0.000	0.000	0.000	0.000	0.000	0.526	1.022	1.135	0.558	0.569	0.581	0.592	0.604	0.616	0.629	0.641	0.654	0.667	0.681	0.694	0.708	0.722	0.737
Transformer #2	23130	0.000	0.000	0.000	0.000	0.000	0.197	0.153	0.282	1.092	1.114	1.137	1.159	1.182	1.206	1.230	1.255	1.280	1.306	1.332	1.358	1.385	1.413	1.441
Circuit 54/103	21512	0.000	0.000	0.000	0.000	0.000	0.012	0.032	0.238	0.013	0.013	0.013	0.013	0.014	0.014	0.014	0.015	0.015	0.015	0.015	0.016	0.016	0.016	0.017
Circuit 53/103	21512	0.000	0.000	0.000	0.000	0.000	0.488	0.144	0.055	0.518	0.529	0.539	0.550	0.561	0.572	0.584	0.595	0.607	0.619	0.632	0.644	0.657	0.670	0.684
Circuit 51/103	21512	0.000	0.000	0.000	0.000	0.000	0.488	0.042	0.296	0.518	0.529	0.539	0.550	0.561	0.572	0.584	0.595	0.607	0.619	0.632	0.644	0.657	0.670	0.684
BT/103	21512	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RINDGE RD. 4KV	1730	0.732	0.832	0.610	0.680	0.805	0.721	0.722	0.791	0.807	0.823	0.840	0.857	0.874	0.891	0.909	0.927	0.946	0.965	0.984	1.004	1.024	1.044	1.065
Circuit #35	1815	0.384	0.384	0.403	0.416	0.409	0.333	0.359	0.371	0.353	0.360	0.367	0.375	0.382	0.390	0.398	0.406	0.414	0.422	0.430	0.439	0.448	0.457	0.466
Circuit #36	1815	0.551	0.551	0.595	0.601	0.601	0.615	0.583	0.647	0.660	0.673	0.686	0.700	0.714	0.728	0.743	0.758	0.773	0.788	0.804	0.820	0.837	0.853	0.870
RIVER ST.	16830	0.495	0.495	0.495	0.530	0.637	0.700	0.710	0.729	0.779	0.795	0.811	0.827	0.844	0.861	0.878	0.895	0.913	0.931	0.950	0.969	0.988	1.008	1.028
FitchburgPaperCo.	5235	0.408	0.450	0.476	0.475	0.508	0.521	0.564	0.681	0.638	0.650	0.663	0.677	0.690	0.704	0.718	0.732	0.747	0.762	0.777	0.793	0.809	0.825	0.841
Circuit #27	8400	0.579	0.556	0.541	0.335	0.571	0.328	0.357	0.266	0.348	0.355	0.362	0.369	0.376	0.384	0.392	0.399	0.407	0.415	0.424	0.432	0.441	0.450	0.459
Circuit #28	9600	0.000	0.000	0.000	0.487	0.667	0.800	0.724	0.611	0.849	0.866	0.883	0.901	0.919	0.937	0.956	0.975	0.995	1.015	1.035	1.056	1.077	1.098	1.120
S.FITCH 4KV	3530	0.507	0.488	0.424	0.433	0.452	0.452	0.406	0.461	0.470	0.479	0.489	0.499	0.509	0.519	0.529	0.540	0.550	0.561	0.573	0.584	0.596	0.608	0.620
Circuit #6	1450	0.774	0.754	0.629	0.576	0.669	0.761	0.583	0.577	0.808	0.824	0.841	0.857	0.874	0.892	0.910	0.928	0.946	0.965	0.985	1.004	1.024	1.045	1.066
Circuit #12	1450	0.305	0.285	0.324	0.318	0.318	0.397	0.358	0.424	0.421	0.430	0.439	0.448	0.457	0.466	0.475	0.484	0.494	0.504	0.514	0.524	0.535	0.546	0.557
SUMMER ST.13.8	38530	0.407	0.407	0.366	0.382	0.390	0.365	0.395	0.403	0.411	0.419	0.427	0.436	0.445	0.454	0.463	0.472	0.481	0.491	0.501	0.511	0.521	0.531	0.542
#3/103	8400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
#3A/103	14400	0.487	0.480	0.674	0.460	0.480	0.467	0.438	0.452	0.495	0.505	0.515	0.526	0.536	0.547	0.558	0.569	0.580	0.592	0.604	0.616	0.628	0.641	0.653
#4/103	8400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
#5/103	6480	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
#9/103	14400	0.373	0.373	0.373	0.560	0.400	0.367	0.374	0.381	0.389	0.397	0.370	0.413	0.421	0.430	0.438	0.447	0.456	0.465	0.474	0.484	0.493	0.503	0.513
#38/103	10200	0.249	0.235	0.241	0.256	0.255	0.269	0.359	0.366	0.374	0.379	0.389	0.583	0.595	0.606	0.619	0.631	0.644	0.656	0.670	0.683	0.697	0.711	0.725
#39/103	10200	0.392	0.392	0.406	0.435	0.447	0.365	0.383	0.908	0.926	0.945	0.963	0.983	1.002	1.022	1.043	1.064	1.085	1.107	1.129	1.151	1.174	1.198	1.222
#40/103	9200	0.348	0.339	0.339	0.339	0.330	0.330	0.277	0.344	0.351	0.358	0.365	0.372	0.380	0.387	0.395	0.403	0.411	0.419	0.428	0.436	0.445	0.454	0.463
#01/103	84000	0.000	0.000	#VALUE!	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
#02/103	64000	0.000	0.000	#VALUE!	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
#08/103	27500	0.000	0.000	#VALUE!	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
[illegible]	[illegible]	0.000	0.000	#VALUE!	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Loading In Per Unit of Rating

LOCATION	PEAK RATING	1991 PK	1992 PK	1993 PK	1994 PK	1995 PK	1996 PK	1997 PK	1998 PK	1999 PK	2000 PK	2001 PK	2002 PK	2003 PK	2004 PK	2005 PK	2006 PK	2007 PK	2008 PK	2009 PK	2010 PK	2011 PK	2012 PK	2013 PK
TOWNS. 10.5 MVA	12020	0.655	0.683	0.647	0.683	0.846	0.847	0.811	0.881	0.898	0.916	0.935	0.953	0.972	0.992	1.012	1.032	1.053	1.074	1.095	1.117	1.139	1.162	1.185
Circuit #15 Alcon	4800	0.622	0.695	0.662	0.892	0.883	0.987	0.000	0.000	1.047	1.068	1.090	11.091	11.312	11.539	11.769	12.005	12.245	12.490	12.740	12.994	13.254	13.519	13.790
Circuit #16 Harbor	4800	0.519	0.568	0.525	0.522	0.694	0.682	0.830	0.770	0.724	0.738	0.753	0.768	0.784	0.799	0.815	0.832	0.848	0.865	0.883	0.900	0.918	0.937	0.955
Circuit #17 Center	4800	0.498	0.438	0.444	0.435	0.652	0.507	0.499	0.662	0.538	0.549	0.560	0.580	0.591	0.603	0.615	0.627	0.640	0.653	0.666	0.679	0.693	0.707	0.721
Circuit #17A	4800	0.000	0.000	0.000	0.000	0.519	0.000	0.499	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WALLACE RD.SUB	3000																							
Circuit #41																								
Circuit #5	2200																							
Circuit #8	1450																							
Circuit #14	2200																							
WEST FITCH.SUB	1710	0.411	0.398	0.439	0.459	0.398	0.432	0.418	0.494	0.458	0.467	0.477	0.486	0.496	0.506	0.516	0.526	0.537	0.548	0.559	0.570	0.581	0.593	0.605
Circuit #26	1450	6.895	0.695	0.761	0.736	0.721	0.754	0.721	0.768	0.801	0.817	0.833	0.850	0.867	0.884	0.902	0.920	0.938	0.957	0.976	0.996	1.015	1.036	1.056
Circuit #27	1450	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.650	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
W.TOWNSEND	5880	0.674	0.662	6.743	1.343	0.837	0.724	0.706	0.734	0.769	0.784	0.800	0.816	0.832	0.849	0.866	0.883	0.900	0.919	0.937	0.956	0.975	0.994	1.014
Circuit#18(W.Towns)	5300	0.308	0.317	0.314	0.362	0.333	0.345	0.349	0.367	0.366	0.373	0.381	0.388	0.396	0.404	0.412	0.421	0.429	0.438	0.446	0.455	0.464	0.474	0.483
Circuit #19 (Ashby)	5300	0.377	0.368	0.380	0.383	0.414	0.405	0.371	0.427	0.429	0.438	0.447	0.455	0.465	0.474	0.483	0.493	0.503	0.513	0.523	0.534	0.544	0.555	0.566

EXHIBIT F

DRAFT

TO MMB
&
PJB
3-12-96

#8 Feeder / Fitchburg Sentinel Outage Analysis

March 12, 1996

DRAFT

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Introduction

This report summarizes the events and subsequent analysis resulting from three primary cable failures on #8 Feeder. These failures resulted in service restoration duration ranging from 8 to 16 hours. The analysis reviewed the unique characteristics of the existing paper and lead primary cable system and developed recommendations to improve the system's operating capability and minimize service restoration time.

I. #8 Feeder Study - Downtown Fitchburg Network System

A. System Capability Analysis

The normal supply for the #8 Feeder is from the Electric Station transformer (69 - 13.8kV) which has a Delta connected 13.8kV secondary. Feeder #8 has an alternate source via the Wallace Rd. Substation, which could potentially be used to provide a backup for customers (such as the Sentinel) tapped radially off the primary network feeder. However, the capacity of this source was unknown. Furthermore, the nature of the interconnected secondary network requires all network transformers be off-line if fed from the alternate source; Wallace Road is 13.8kV Wye and the Electric Station is 13.8kV Delta. As a result, the Wallace Road source has not typically been used .

Based on the most recent failures and the subsequent tests, most problems on #8 feeder are located close to the Electric Station portion of this feeder. If the Wallace Rd. tie could be used (after appropriate sectionalizing) to supply some customers while a faulted cable is repaired, the risk of an extended outage to customers beyond the faulted section is significantly reduced.

In order to establish the capability of this tie, it was necessary to construct a computer model, and perform a voltage drop/thermal loading study. As the engineering data for the model was not readily available, considerable effort was required to field check overhead circuits, and collect data on the underground feeders. Protection issues were reviewed as well to confirm the ability to respond adequately to faults, and to minimize the number of customers experiencing an outage subsequent to a permanent fault.

An overview map for feeders #1 (emanating out of Beech Street to Wallace Road) and #8 was also developed.

B. System Capability Analysis Results

Thermal/Voltage

The study indicated that the system currently has the capability to feed the entire #8 feeder non-network load for the foreseeable future.

Protection

Sensitivity to faults is good. However, coordination between breakers 1/103 at Beech Street and 8/103 at Wallace Rd. is marginal. For the time being this represents a reasonable risk. However, a detailed coordination analysis should be performed.

Operations:

The fundamental result of this study established that the system can support alternate feed to the Sentinel and other non-network customers on the Rollstone St. tap with no enhancements. We will need to confirm with operations that proposed switching is appropriate.

Proposed switching for a fault on the Electric Station side of the Rollstone St. switchgear; assuming the radial tap from the switchgear is operational. The switching outlined below assumes all appropriate cable testing has been performed to avoid closing in to a faulted section and all the applicable network transformers have been removed from the system to prevent an out of phase closure through a transformer.

1. Take network transformer 8N13 off-line.
2. Open or check open 8-114 (Rollstone St. switch)
3. Close or check closed 8-115 (Rollstone St. switch)
4. Confirm that recloser 8/103 at Wallace Rd is set for non-reclosing.
5. Close recloser 8/103.

Depending on the location of the fault, it may be possible to pick up more sections of #8 feeder's non-network load from Wallace Rd. It should be noted that **ALL** network transformers on #8 feeder sections fed via Wallace Rd. must be off-line.

C. Other Options To Reduce Restoration Time

The above discussion establishes that FG&E can provide an alternate supply to the Sentinel, Worker's Credit Union, and the Post Office for cable failure on the main line. However, these customers are still fed via a single radial tap from the switch on Rollstone Street. If the cable failure occurs on that radial tap, then these customers will experience an outage until the cable can be repaired. The following proposals would minimize the duration of or eliminate such an outage:

Proposal 1

Establish a normally open point at the Rollstone Switchgear.

This proposal will allow a faster restoration times for customers on the Rollstone Street tap for main line faults along #8 feeder. After testing the cable on this tap (assuming no fault is found on the tap), the tap can be immediately transferred to the Wallace Rd. tie. Furthermore, the section of #8 Feeder which normally supplies all network and primary customer load would be isolated from faults on the 0.90 mile (about half the feeder length) section fed from Wallace; reducing the length of cable exposure susceptible to a failure.

System modifications:

Extend Feeder #8 to feed network transformer 8N13 from the Electric Station side of the Rollstone Street switchgear. This allows feeder #8 to be fed from an alternate source, without necessitating taking 8N13 off-line. This minimizes the potential for a switching error to occur during service restoration which might lead to an out of phase closure through this network transformer.

1. Disconnect primary tap to 8N13 in MH 39A.
2. Pull cable from MH34A to MH39A (3 manhole-manhole runs totaling 830'.)
3. Tap new cable into feeder #8 at MH 34A.
4. Connect primary tap to 8N13 to new cable in MH39A.

Consideration should be given to providing status indication of Wallace Rd. Breaker 8/103 to the FG&E watch_engineer. No load will normally be fed from the section of cable from Wallace Rd to the normal open point at the Rollstone switch. It will be necessary to know if the 8/103 breaker has tripped, so that faults can be located and repaired quickly. If this paper and lead cable is damaged and left de-energized for an extended period of time moisture will migrate into the cable. Install lightning arresters on both sides of the open switch at Rollstone Street will also enhance the lightning protection afforded to this service aged paper insulation. As this switch will now be an open point, overvoltage protection becomes critical.

Cost: $ 77,049.00

System Configuration: Wallace Rd. 8/103 Closed .

8-115 Open (Rollstone St.)

8-114 Closed (Rollstone St.)

Proposal 2:

Install a spot network to supply the Fitchburg Sentinel, and the Worker's Credit Union.

1. Extend Feeder #11 From Wallace Street to manhole 103A. (4 manhole-manhole runs totaling 1000'.)
2. Install a new vault, containing 2 500 kVA network transformers with protectors.
3. Install approximately 50' of duct from manhole 103A to the new vault.
4. Run 2 50' runs of cable from new vault to manhole 103A for connection between network units and feeders #8 and #11.
5. Install secondaries in customer owned duct (approximately 120' of 3-500s per phase).
6. Run secondaries to Worker's Credit Union (approximately 140' of 2-500s per phase) from new vault, to MH 103A to MH104C to basement of worker's credit union.

Cost: $ 503,325.00

System Configuration:

Proposal #3:

Extend Feeder #11 and install a new switch in a sidewalk vault.

1. Extend Feeder #11 From Wallace Street to manhole 103A. (4 manhole-manhole runs totaling 1000'.)
2. Install a new vault, containing a two-feed switch.
3. Install approximately 50' of duct from manhole 103A to the new vault.
4. Replace customer's primary cable with EPR insulated cable.

5. Run 2 50' runs of cable from new vault to manhole 103A for connection between switch and feeders #8 and #11.

The switch would be specified to accept standard 200 amp elbow connectors from the customer's cable. The proposed cable would be EPR insulation construction.

Cost: $ 245,061.00

System Configuration:

Proposal #4: Replace all the existing paper and lead cable on the Rollstone Street radial spur with EPR cable.

Vault 224V - MH 34A	100'
MH34A - MH 103A	111'
MH103A - MH104C	72'
MH104C - Worker's CU	50'
MH34A - MH36A	151'
MH36A - MH119A	201'
MH119A - Post Office Vault	51'
P.O. Vault - Transformer	150'
Total for this radial spur	886'

Cost: $ 113,406.00

D. Cable Testing

A portion of #8 feeder, from the Electric Station to the switch at Day Street, was de-energized and tested. The test was performed on three sections of this feeder; from the Electric Station to the switch on Sawyer Passway 8 -110, the radial emanating from the switch 8 -110 to Micron Products and Century Plastics and the third section from the Sawyer Passway switch 8 - 111 to the switch on Day Street 8 - 210. These three sections of cable could be removed from service with minimal interruption of service to our customers. Micron products is the only customer on this section of cable and they were willing to work with FG&E to schedule a shutdown during their off production hours.

Two of the failures on #8 Feeder occurred within this section of cable selected for testing. Both of these failures were splice failures. Coincidentally, both of these splices were in the same manhole on Sawyer Passway; manhole 3-A.

Cable test results, although producing exact number, do not give exact indication of the cable's condition or predict when a failure will occur. The data is viewed relative to data for this type of cable or compared against historical data captured on the same cable. Test results do provide a means of assessing the relative condition of the cable and provide an indication of the likelihood of an additional cable failure. However, predicting when or if the cable will fail is not achievable. Varnished cambric and paper and lead cable is very reliable and is less susceptible to conditions which might otherwise cause a failure in a conventional poly cable. Historical test data was not recorded for these cables. This cable is constructed as a single run of three separate conductors bundled within a lead sheath. Each conductor is constructed of oil impregnated paper or varnished cambric for insulation. The single conductor is then wrapped with a perforated copper tape shield which establishes an interface between adjacent conductors and the exterior lead sheath. Records indicate this cable was installed in September 1948. Reference material and historical test records were not available for this type and vintage cable. American Electric Testing Company was used to perform the initial tests and as consultants to discuss the test results.

- Electric Station - 8 -110 The insulation resistance test results indicate all three phase of this conductor are in good condition. The values range from 3,333 to 16,000 Megohms. The corresponding leakage currents were less than 1.8 Microamps and remained constant throughout the test.

- 8 - 110 to Micron Products/Century Plastics One phase (C) tested poor on this section of cable. Both cable resistance and leakage current on phase C tested a factor of ten higher than phases A and B and the section of cable from Sawyer Passway previously mentioned.

- 8- 111 to 8 - 210 (Day Street Switch) All three phases of this cable tested poor. This cable is a single, three conductor paper and lead cable. If moisture has penetrated the lead sheath, it will migrate through the insulation of all three conductors. The poor insulation reading and corresponding high leakage current indicate insulation degradation has and is occurring. The values of insulation resistance and leakage current were also a factor of ten different from the "good" cable emanating from the Electric Station.

The cable testing data corroborates the suspicion that moisture is present within this three conductor cable system. The cable testing data can not predict when another failure will occur. A construction program should be initiated to change out this cable to mitigate the likelihood of additional failures. This change out program should start with manhole 3A on Sawyer Passway and work towards the Day Street switch; manhole by manhole. Changing the conductor one section at a time will allow the remaining sections to be tested to establish if the "bad" section has been removed. The change out should continue until the cable test results indicate the bad cable has been removed. Consideration should be given to adopting a policy which calls for new cable to be installed whenever this existing cable fails. Although this may increase the overall service restoration time (changing cable vs. splicing), the overall system performance should improve by installing new cable.

E. G&W Switch

During the course of this study the operating capability of the G&W submersible oil switch at Workers Credit Union was brought into question. The follow up investigation confirmed the questions expressed about this switch. G&W had issued product advisory letters for this type of switch in 1983 and 1985. The letters stated that energized operation of these switches has resulted in failures causing serious injuries and fatalities. Engineering contacted other New England utilities to discuss these switches and most utilities had removed them from their system shortly after the second letter was issued from the vendor. Operations is currently conducting a survey of the remaining in service, submersible, oil filled, switches to collect name plate data for Engineering to review.

A product notification was issued to FG&E Operations that this switch must be operated de-energized. This operating limitation requires the #8 Feeder to be de-energized to allow this switch to be opened. Opening #8 feeder causes an interruption to all the non-network customers tapped off this feeder until this switch is opened. The objective of this study was to improve service reliability to these customers, not decrease it. This operating restriction increases the anticipated duration of service restoration for a network cable failure on the #8 Feeder. Additional analysis investigated the requirements for this switch. In general, the requirements and location of all submersible switches will be reviewed when the field information is collected from Operations. Switches will not be replaced on a one for one basis without a complete review.

The specific switch at Worker Credit Union will need to be replaced (material cost only $7,500.00). This switch is used to disconnect the three phase transformer from the system. All three phase network transformers (all three phase distribution transformers at FG&E) have Delta connected high voltage primaries. This highside primary configuration requires a three phase, gang operated, device to energize or de-energize the transformer. Delta connected primaries are susceptible to ferroresonance during switching and a three phase gang operated devices mitigates the potential of a ferroresonance condition occurring.

F. Emergency Back up Generator

Consideration should be given to providing the Sentinel with a natural gas fired emergency generator equipped with an automatic start and transfer switch. The unique requirements of this customer and their inability to sustain an interruption in electric service lend themselves to providing a second energy source for operation. This alternative may also be cost effective when compared with the various distribution system enhancement options discussed within this report. FG&E has an 8 inch, high pressure, gas line located in the street directly in front of the Sentinel. A preliminary cost estimate for a 300kVA generator is approximately $75,000.00. Cost is directly proportional to kVA capacity when procuring a generator. Discussions should be initiated with the Sentinel concerning their ability to segment their load into critical and non-critical. Critical loads would be associated with operations essential to produce their product. If the critical load can be structured not to exceed 100kVA the corresponding generator cost is reduced by a factor of 8 to 10.

G. Primary Network Feeder Analysis

Three 13.2kV primary high voltage feeders constitute the sources which supply the network system at FG&E; Feeders 8, 10A and 11. Cables for these three Feeders emanate from the Electric Station along Sawyer Passway and proceed north along Main Street. All three Feeders are principally constructed of paper and lead or varnished cambric and lead cables. The table below summarizes the existing Feeders capability, current rating and peak loading during a first contingent condition.

All values are in kVA

	8 Feeder	11 Feeder	10A Feeder	3PH Total
Transformation	2800	2550	2700	8050
Peak Demand	2880	3120	1440	7440
Feeder's Rating	6600	6600*	3100	16300

* This rating needs to be reviewed. During a recent cable failure along Sawyer Passway three separate, 250 MCM, CU, single conductors were installed replacing the single cable, 350 MCM, CU, three conductor cable.

The maximum Feeder ratings are based on the maximum conductor thermal rating. Feeders 8 and 11 are single cable, 350 MCM, CU, three conductor, paper and lead. Feeder 10A is a single cable, 2/0 AWG, CU, three conductor, paper and lead.

Generating the table above for contingent loss of 11 Feeder looks like:

All values are in kVA

	11 Feeder	3PH Total	
Transformation	OOS	5500	
Peak Demand		6140	*(GE is transferred to 17 Feeder.)*
Feeder's Rating		9700	

This basic analysis demonstrates the remaining network transformers will be operating at approximately 112% of their nameplate thermal rating. Network transformer ratings are established using the same ANSI standard technique applied to distribution and power transformers, however, additional factors such as the vault's thermal design, what other type of equipment is present within the vault and consideration to the 50 degree average winding rise design need to be considered. At this time, these factors are not known for each of FG&E's transformer vaults. This information will need to be established as part of a comprehensive downtown Fitchburg network study.

H. Secondary Network Analysis

The option of sifting the Sentinel's load (approximately 270 kVA peak demand) to the secondary network system was investigated. A comprehensive study and analysis of the capability of FG&E's secondary network system does not exist at this time. Given the time constraint of this study, the system was reviewed on an overview basis (reference **Primary Network Feeder Analysis** within this report) and the following conclusions were established.

Given the existing network loading and available transformation capacity feeding into the system today, during the first contingent loss of a network feeder (8 or 11), the remaining transformation is predicted to operate at 112 percent of their aggregate thermal rating. This transformation thermal limitation will be lifted when the 1996 Capital project to change out all PCB network transformers is complete.

However, a comprehensive secondary network loadflow study would still be needed before additional load is added to this system. FG&E's records indicate minimal changes have been made to the secondary network conductors since they were installed. The initial design of this system consisted of predominately 150 and 300 kVA network transformers. I speculate the secondary system's design was optimized given these initial 150 and 300 kVA transformer installations. The secondary network consists predominately of an interconnected grid of 250 and 400 MCM, 600 volt cables. Detailed maps and records exist for this system, however, it will be an arduous task to perform the research necessary to construct a network loadflow model. The first step in this process would be to transfer the existing drawing into an electronic format to make them more legible. This information is crucial to developing an accurate network loadflow model. This electronic conversion process should be integrated as part of an overall network loadflow analysis and will be brought to the table as part of the FG&E electric distribution map consolidation project currently ongoing with Unitil Engineer and Planning.

I. General Network System Design

As the FG&E system moves forward in time, consideration should be given to removing the customers currently fed from radial taps off the network Feeders. This will begin the transition of converting the network Feeders back into pure network Feeder cables. The lack of information, documentation and system studies make an expeditious transition difficult. In addition lacking the information previously mentioned it is difficult to quantify the resources and overall cost associated with implement this change. During the last few months and years of operating and examining this system, it is evident the current practice of establishing radial taps from the existing network Feeder lines may have been the lowest cost alternative available to meet the load additions in this portion of our system. Consideration should be given to constructing an additional 13.8kV Feeder emanating from the Electric Station to supply these non-network customers. This new Feeder could use the current alternate supply available from Wallace Rd via Beech Street as a back up. The new system design should strive to provide enough flexibility to minimize the number of customers effected by a cable failure and reduce the service restoration time. Although the out of phase condition would still exist at the normal open point between the two sources, these customers would have two independent sources supplying service to buildings. The system design would need to include a sufficient amount of switches to provide the flexibility to isolate only the faulted section of cable involved and restore service to the remaining customers while the damaged cable is repaired.

II. Conclusions And Recommendations

1. A natural gas fired generator should be installed at the Sentinel to provide the level of service reliability they require. The installation of a natural gas fired generator appears to be the most cost effective short term solution.

2. The #8 Feeder cable should be replaced on a manhole by manhole basis until the poor cable is removed.

3. Lighting arrester should be installed on the normal open point of all the underground network Feeder cables to decrease the cable's susceptibility to a lighting induced failure.

4. The G&W switch at the Worker Credit Union should be replaced to improve system restoration time and remove this known defective product from our system.

5. The remaining in service oil filled submersible switches should be surveyed to establish if they fall within the scope of the G&W product advisory.

6. Customers tapped off the current 13.8kV network Feeders should be transferred to a new circuit. The new circuit would emanate from the Electric Station Substation and use the existing alternate source from Wallace Road via Beech Street as a back up. This new circuit would provide these customers the level of service afforded an underground customer with a loop feed.

7. A comprehensive primary and secondary network loadflow analysis should be conducted. This study would model the 13.8 kV and interconnected 125/216 volt system. Ratings for the network transformers, vaults and cables should be reviewed as part of this study.

8. FG&E needs to develop a specification for cable which can be used in place of the existing lead cable. The material and work procedures required to perform transition splices (lead to poly) needs to be established.

9. FG&E should implement a policy to replace failed network Feeder lead cable with EPR cable.

III. Summary

Paper and lead and varnished cambric and lead cable systems are very reliable. However, when a cable failure occurs the restoration time is excessive compared to current poly cable or overhead distribution systems.

The most cost effective, short term, solution to provide a high level of service to the Fitchburg Sentinel would be to install a natural gas fired back up generator.

The Fitchburg Gas and Electric Light Company's downtown secondary network system has historically performed with a high level of service reliability. FG&E's ability to continue to connect customers to this secondary network system or expand the current system is limited by a lack of studies and documentation about the capability of the system. Customer who are tapped off the 13.8kV lines which supply the network (non-network customers) will continue to experience long duration outages should cable failures occur on the paper and lead system until significant system changes are instituted.

Fitchburg should initiate the construction of a new Feeder into the downtown system to pick up these non-network customers and use the existing alternate supply from the Wallace Road Substation as a back up for this new Feeder.

This study brought to light additional system elements which need attention. These elements will be evaluated on a case by case basis and corrective actions initiated as appropriate.

EXHIBIT G

LEGEND

▭	VAULT
□	MANHOLE
———	13.8kV PRIMARY UNDERGROUND FEEDER MAINLINE (8, 10, 10A, 11, 17)
———	OTHER PRIMARY UNDERGROUND FEEDER
- - - -	UNDERGROUND NETWORK SECONDARY

THIS DRAWING SUPERCEDES DRAWING #F-3-214

DRAWN	CMS
CHECKED	MAF
APPROVED	CEC

Unitil

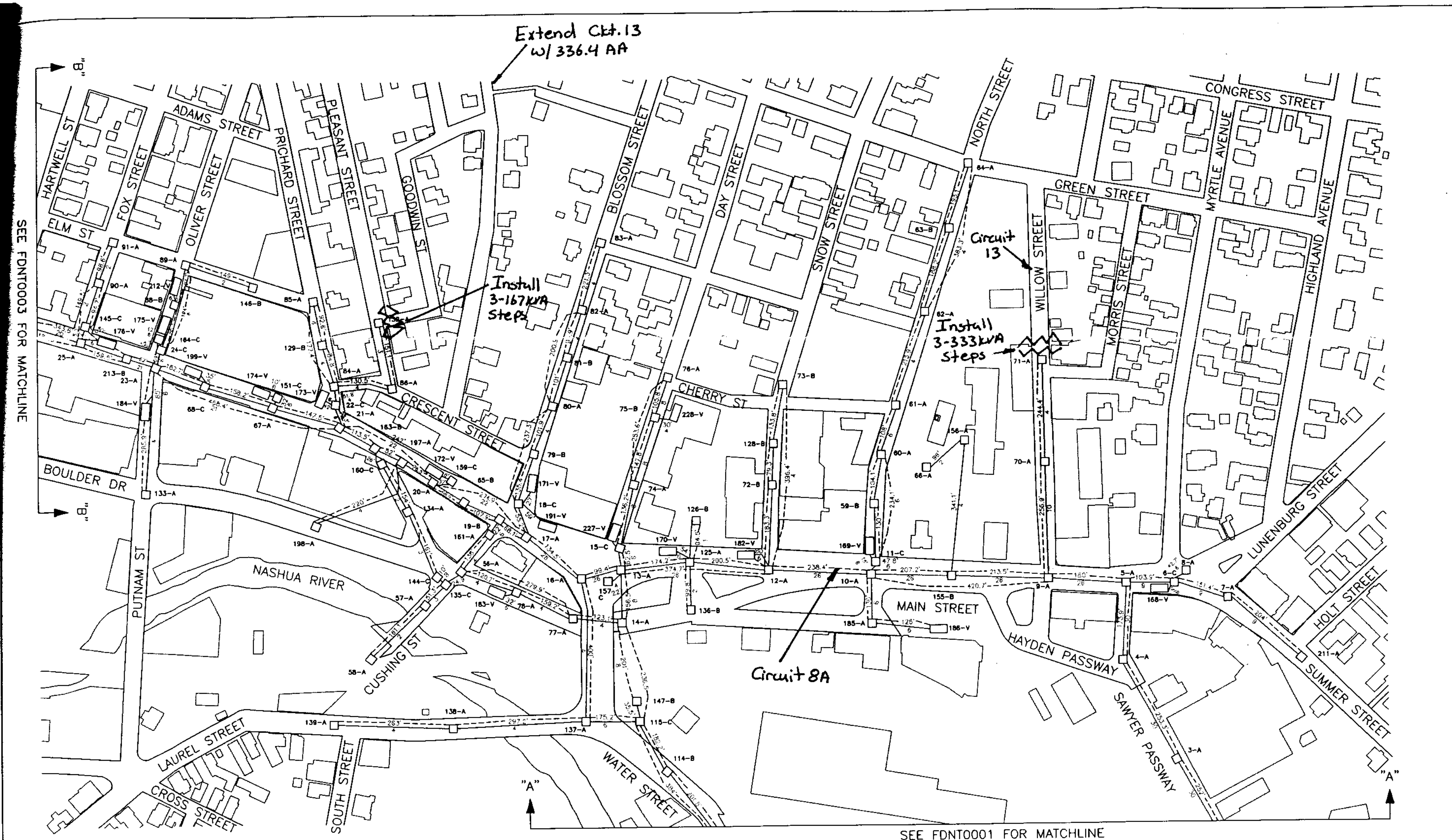
Fitchburg Gas and Electric Light Company

UNDERGROUND NETWORK SYSTEM
PRIMARY AND SECONDARY CABLE
VAULT AND DUCT LOCATION PLAN

SCALE	DATE	SHEET	DRAWING NO.
1" = 100'	10/15/98	1 of 1	FDNT0001

REVISIONS

EXHIBIT H



SEE FDNT0003 FOR MATCHLINE

SEE FDNT0001 FOR MATCHLINE

UNDERGROUND NETWORK SYSTEM
PRIMARY AND SECONDARY CABLE
VAULT AND DUCT LOCATION PLAN

Unitil

Fitchburg Gas and Electric Light Company

DRAWN: CMS
CHECKED: MAC
APPROVED: CEC

SCALE: 1" = 100'
DATE: 10/15/98
SHEET: 1 of 1
DRAWING NO. FDNT0002

REVISIONS

EXHIBIT I

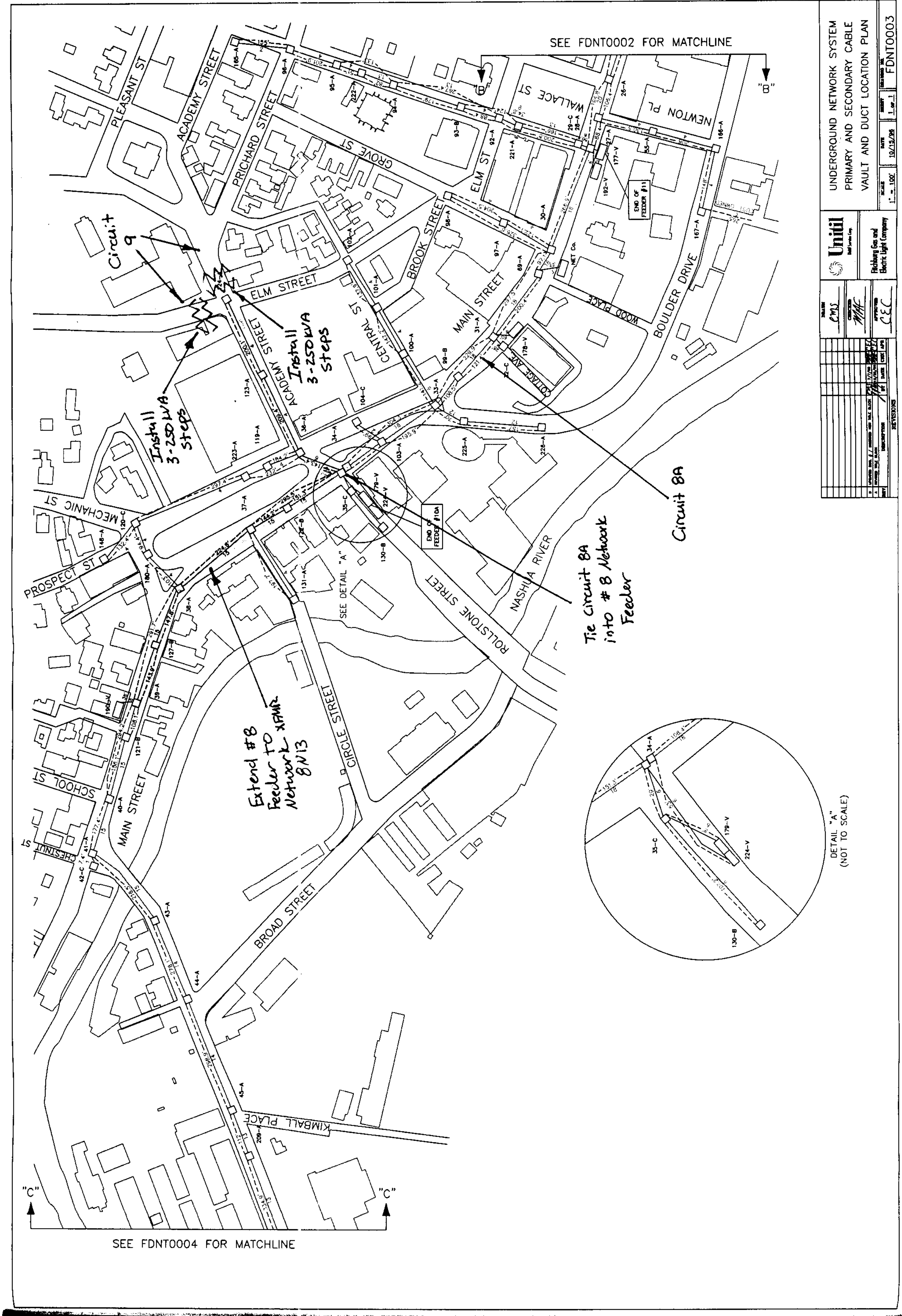

SEE FDNT0002 FOR MATCHLINE
"B"
"B"
SEE FDNT0004 FOR MATCHLINE
"C"
"C"
PLEASANT ST
ACADEMY STREET
PRICHARD STREET
GROVE ST
WALLACE ST
NEWTON PL
ELM ST
BROOK STREET
ELM STREET
CENTRAL ST
MAIN STREET
WOOD PLACE
BOULDER DRIVE
COTTAGE AVE
MECHANIC ST
PROSPECT ST
SCHOOL ST
CHESTNUT ST
CIRCLE STREET
BROAD STREET
ROLLSTONE STREET
NASHUA RIVER
KIMBALL PLACE
SEE DETAIL "A"
END OF FEEDER #11
END OF FEEDER #10A
Circuit 9
Install 3-250KVA steps
Install 3-250KVA steps
Circuit 8A
Tie Circuit 8A into #8 Network Feeder
Extend #8 Feeder to Network XFMR 8N13
DETAIL "A" (NOT TO SCALE)
UNDERGROUND NETWORK SYSTEM
PRIMARY AND SECONDARY CABLE
VAULT AND DUCT LOCATION PLAN
Unitil
Fitchburg Gas and Electric Light Company
1" = 100'
10/15/96
FDNT0003
REVISIONS

EXHIBIT J

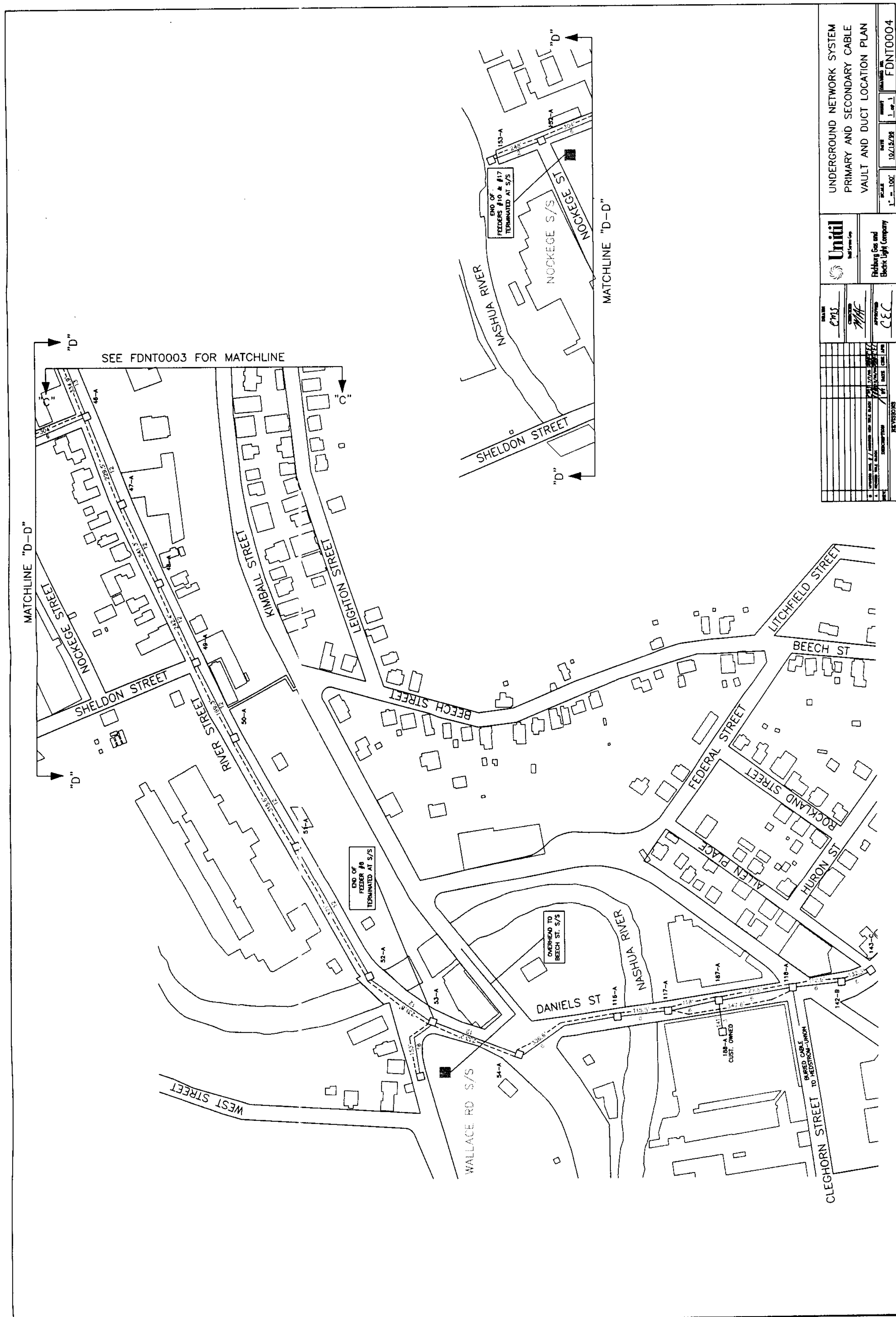
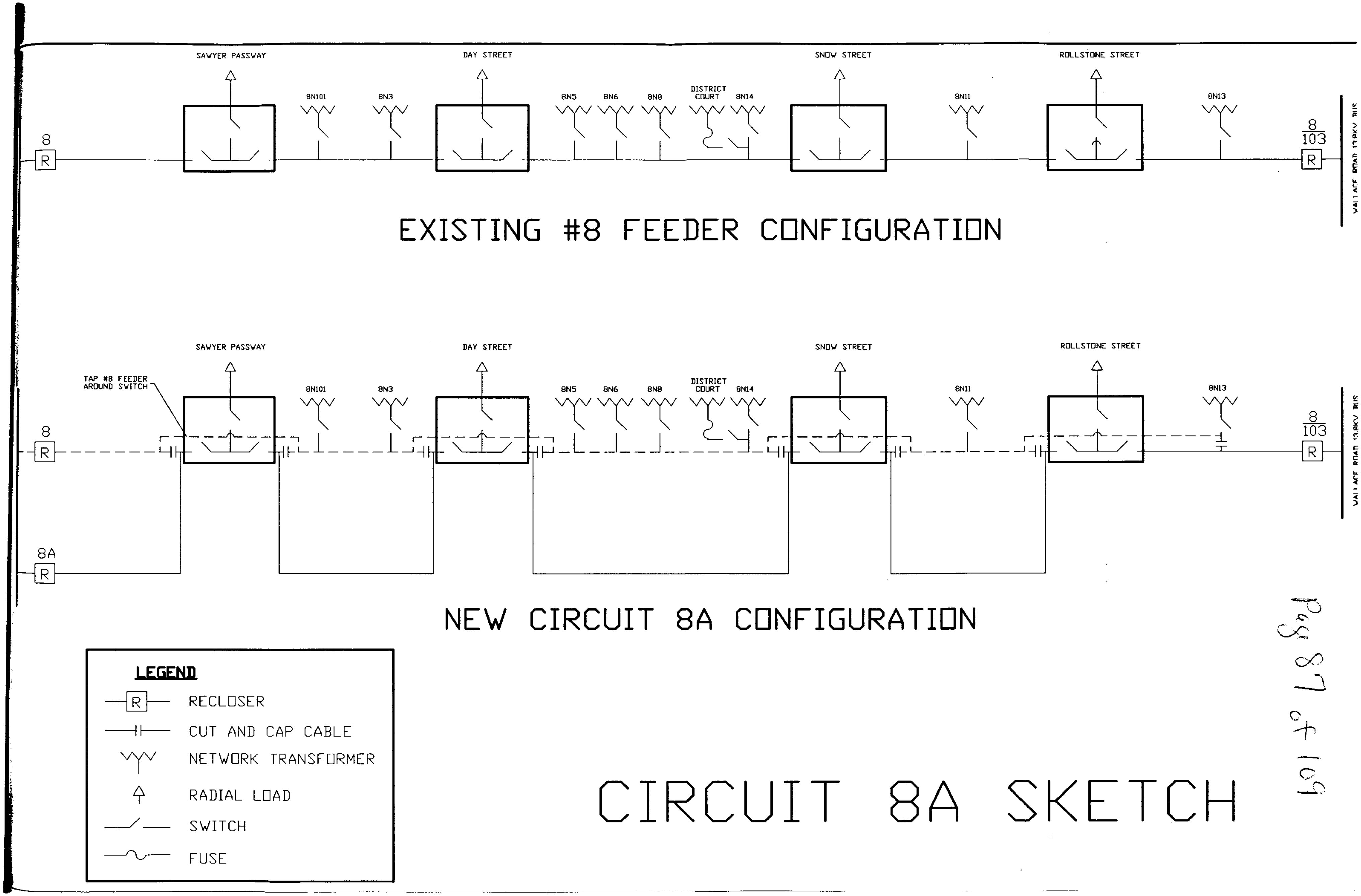
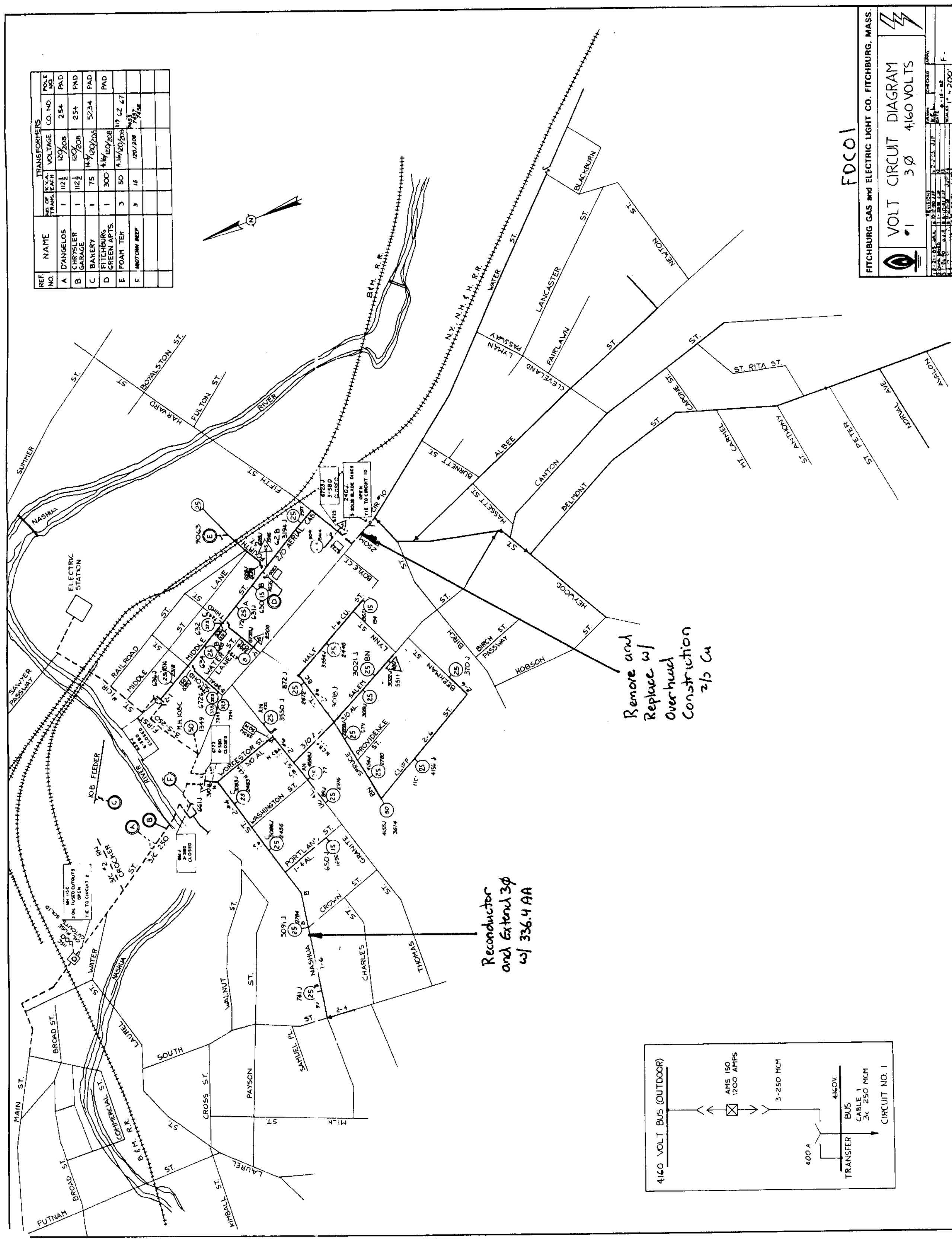

SEE FDNT0003 FOR MATCHLINE
MATCHLINE "D-D"
"C"
"D"
NOCKEGE STREET
SHELDON STREET
RIVER STREET
KIMBALL STREET
LEIGHTON STREET
BEECH STREET
LITCHFIELD STREET
BEECH ST
FEDERAL STREET
ROCKLAND STREET
ALLEN PLACE
HURON ST
DANIELS ST
NASHUA RIVER
WEST STREET
WALLACE RD S/S
CLEGHORN STREET
END OF FEEDER #8 TERMINATED AT S/S
OVERHEAD TO BEECH ST. S/S
BURIED CABLE TO HEDSTROM-UNION
188-A CUST. OWNED
46-A
47-A
48-A
49-A
50-A
51-A
52-A
53-A
54-A
116-A
117-A
187-A
118-A
142-B
143-C
NOCKEGE S/S
NOCKEGE ST
SHELDON STREET
NASHUA RIVER
END OF FEEDERS #10 & #17 TERMINATED AT S/S
153-A
152-A
MATCHLINE "D-D"
UNDERGROUND NETWORK SYSTEM
PRIMARY AND SECONDARY CABLE
VAULT AND DUCT LOCATION PLAN
Unitil
Fitchburg Gas and Electric Light Company
SCALE 1" = 100'
DATE 10/15/98
SHEET 1 of 1
DRAWING NO. FDNT0004
DRAWN
CHECKED
APPROVED
REVISIONS
DESCRIPTION

EXHIBIT K



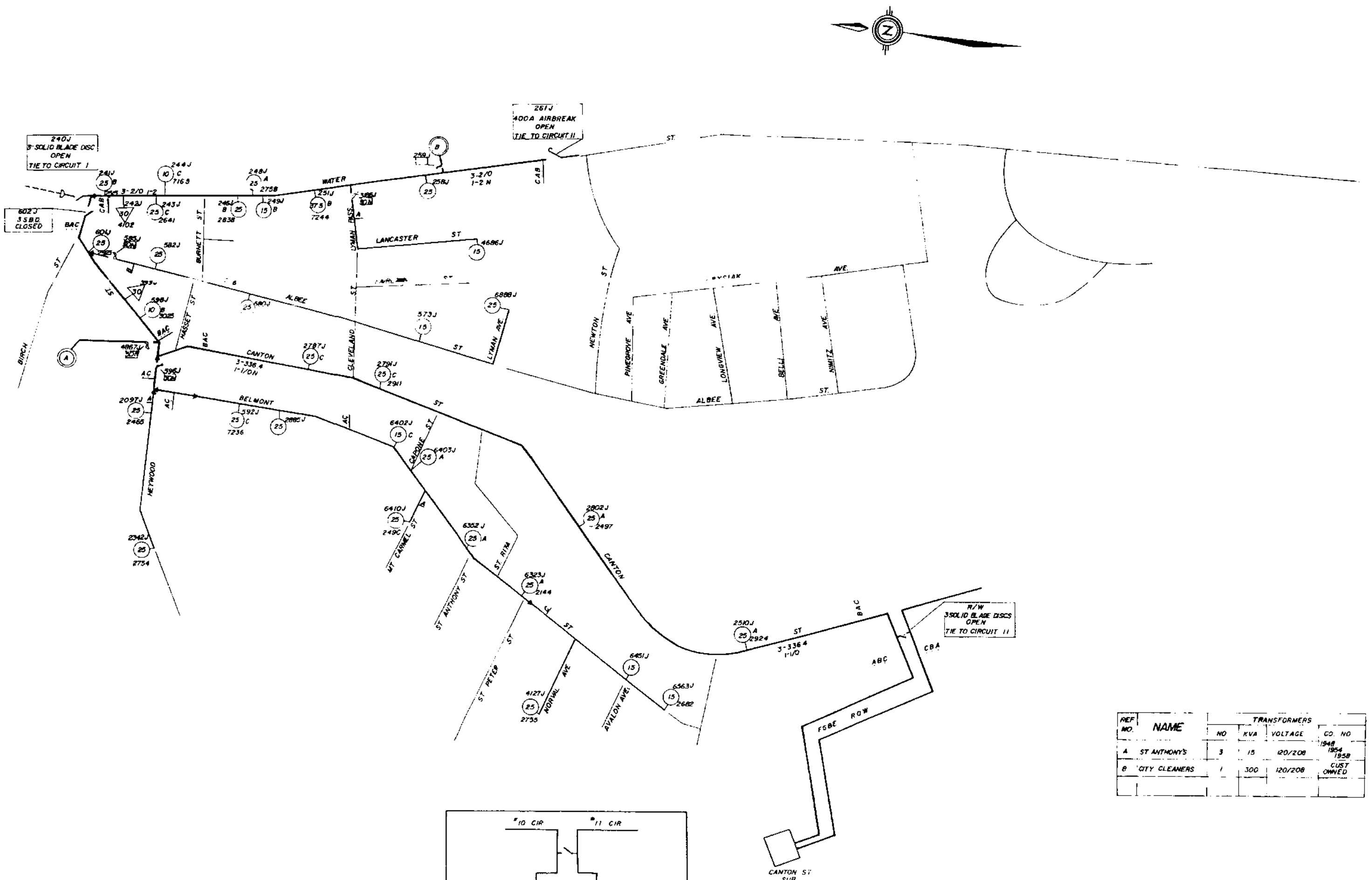
CIRCUIT 8A SKETCH

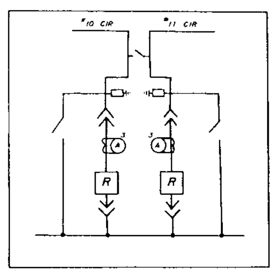
EXHIBIT L



FITCHBURG GAS and ELECTRIC LIGHT CO. FITCHBURG, MASS.
VOLT CIRCUIT DIAGRAM
#1 3Ø 4,160 VOLTS
FOCO1
TRANSFORMERS
REF NO. | NAME | NO. OF TRANS. | K.V.A. EACH | VOLTAGE | CO. NO. | POLE NO.
A | D'ANGELOS | 1 | 112½ | 120/208 | 254 | PAD
B | CHRYSLER GARAGE | 1 | 112½ | 120/208 | 254 | PAD
C | BAKERY | 1 | 75 | 120/208 | 5234 | PAD
D | FITCHBURG GREEN APTS. | 1 | 300 | 120/208 | | PAD
E | FOAM TEK | 3 | 50 | 120/208 | |
F | MOTOWN BEEF | 3 | 15 | 120/208 | |
4160 VOLT BUS (OUTDOOR)
AMS 150 1200 AMPS
3-250 MCM
4160V.
400 A
TRANSFER BUS
CABLE 1 3c 250 MCM
CIRCUIT NO. 1
ELECTRIC STATION
JOB FEEDER
NASHUA RIVER
B.&M. R.R.
N.Y. N.H. & H. R.R.
Remove and Replace w/ Over-head Construction 2/0 Cu
Reconductor and Extend 3Ø w/ 336.4 AA

EXHIBIT M





REF NO.	NAME	TRANSFORMERS NO	KVA	VOLTAGE	CO. NO
A	ST ANTHONY'S	3	15	120/208	1948 1954 1958
B	CITY CLEANERS	1	300	120/208	CUST OWNED

FD210

REVISIONS

FITCHBURG GAS AND ELECTRIC LIGHT COMPANY

FG&E

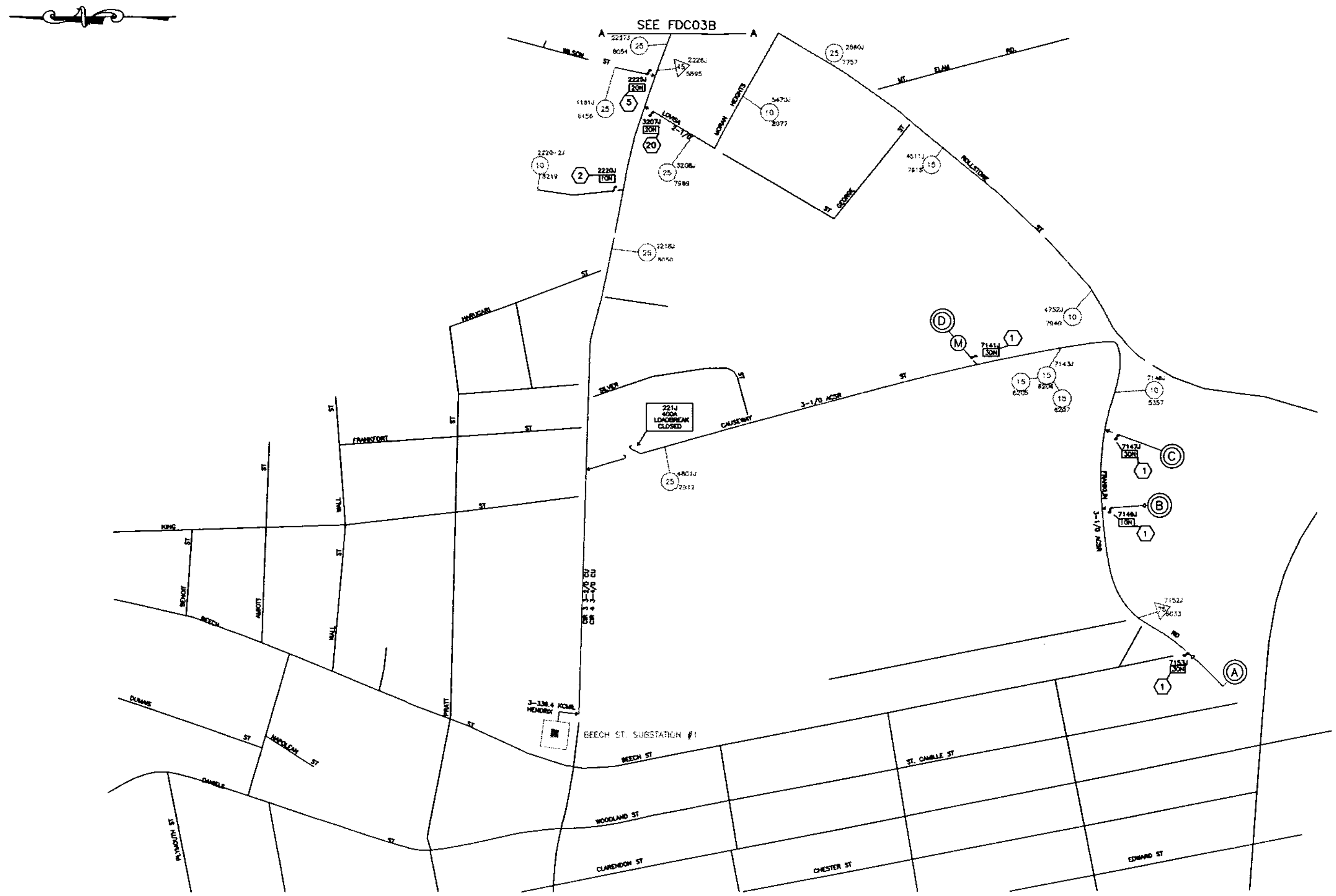
CIRCUIT DIAGRAM
10

4160 VOLTS

CANTON ST SUB

DRAWN BY J.V.P.
DATE 12-23-91
APPROVED BY
SCALES 1" = 200'
F-

EXHIBIT N



REF. NO.	NAME	TRANSFORMERS			
		NO. TRANS.	KVA EACH	VOLTAGE	COMPANY NO.
A	VICTORY SUPERMARKETS	1	300	14400 120/208	5902
B	BELLVUE PLAZA	1	112.5	14400 120/208	
C	PARKHILL PLAZA	3	100	14400 120/208	4806 4807 4836
D	MEMORIAL JR HIGH SCHOOL	1	225	14400 120/208	CUST. OWNED

⬡ DENOTES THE NUMBER OF CUSTOMERS ON A FUSE.

REV.	DESCRIPTION	BY	DATE	CHK	APR
B	UPDATED FOR CONSTRUCTION				
A	GENERAL UPDATE	AJP	7/25/97		

REVISIONS

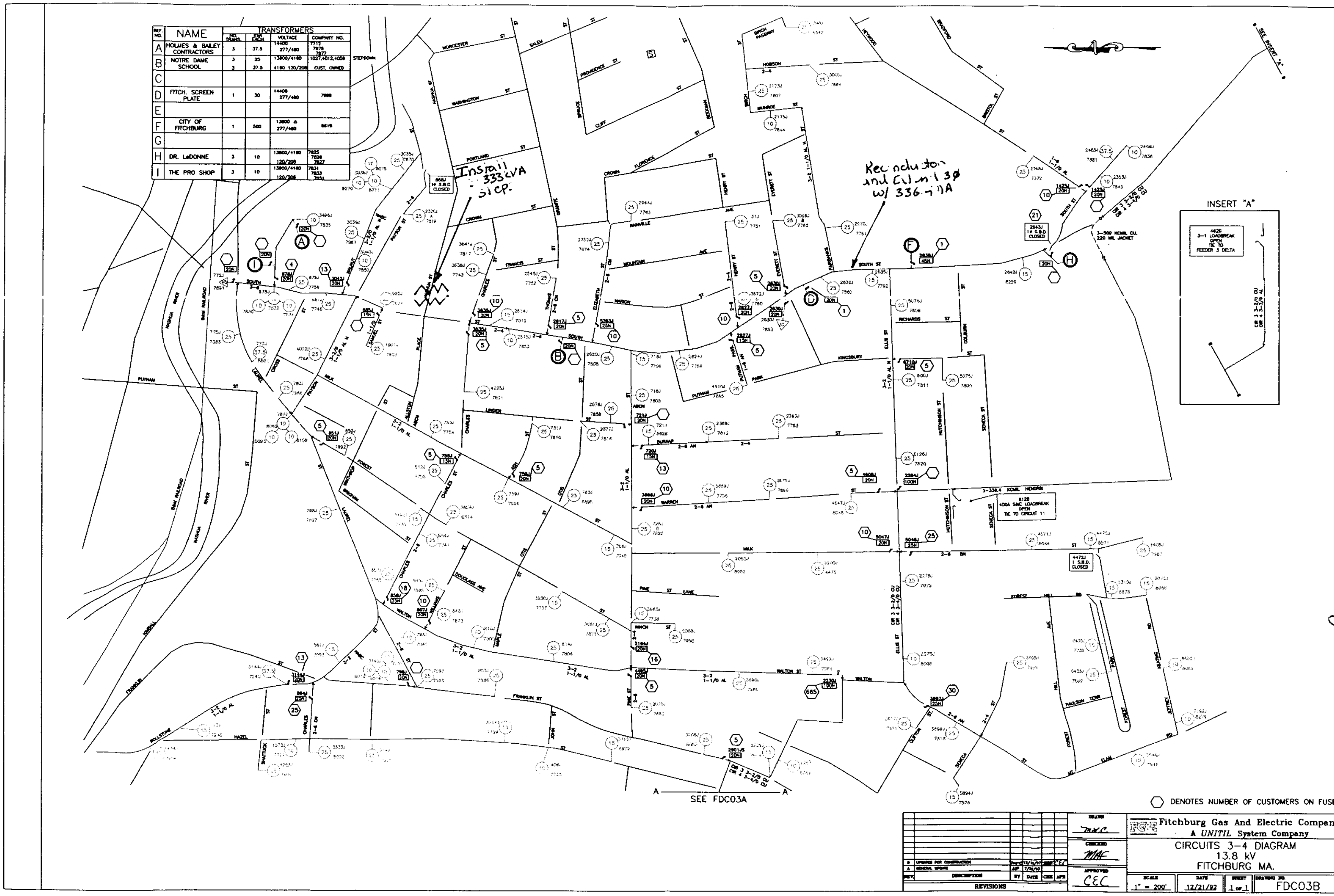
DRAWN: mxc
CHECKED: MAE
APPROVED: CEC

Fitchburg Gas And Electric Company
A *UNITIL* System Company

CIRCUITS 3-4 DIAGRAM
13.8 kV
FITCHBURG MA.

SCALE	DATE	SHEET	DRAWING NO.
1" = 200'	12/21/92	1 of 1	FDC03A

EXHIBIT O



REF. NO.	NAME	TRANSFORMERS NO. TRANS.	KVA EACH	VOLTAGE	COMPANY NO.
A	HOLMES & BAILEY CONTRACTORS	3	37.5	14400 277/480	7712 7876 7877
B	NOTRE DAME SCHOOL	3 3	25 37.5	13800/4160 4160 120/208	1027,4012,4058 STEPDOWN CUST. OWNED
C					
D	FITCH. SCREEN PLATE	1	30	14400 277/480	7999
E					
F	CITY OF FITCHBURG	1	500	13800 Δ 277/480	8619
G					
H	DR. LeDONNE	3	10	13800/4160 120/208	7825 7826 7827
I	THE PRO SHOP	3	10	13800/4160 120/208	7831 7833 7831

Fitchburg Gas And Electric Company
A UNITIL System Company

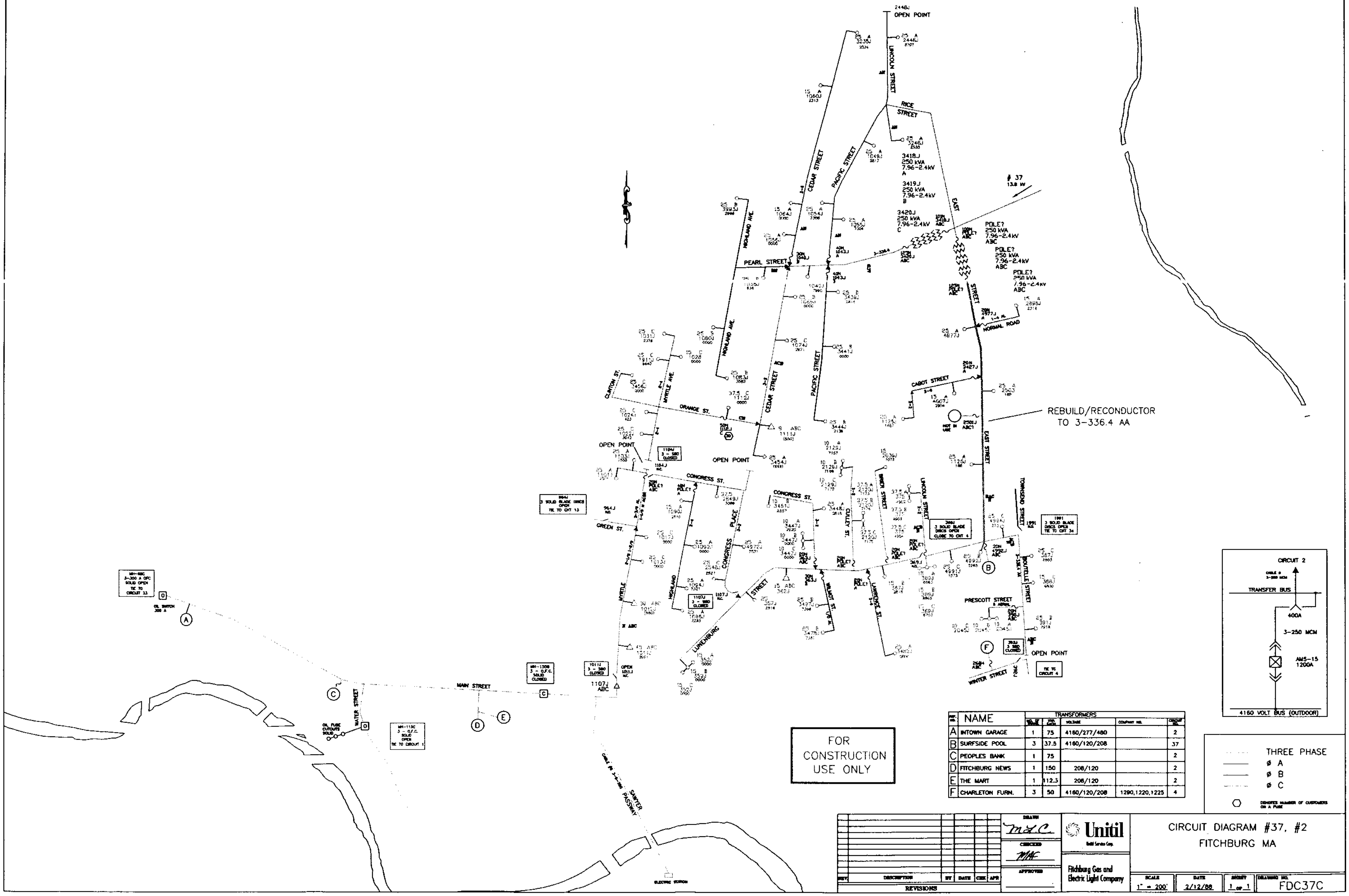
CIRCUITS 3-4 DIAGRAM
13.8 kV
FITCHBURG MA.

DRAWN	CHECKED	APPROVED	SCALE	DATE	SHEET	DRAWING NO.
MKC	MAC	CEC	1" = 200'	12/21/92	1 of 1	FDC03B

REV.	DESCRIPTION	BY	DATE	CHK	APR
B	UPDATED FOR CONSTRUCTION				
A	GENERAL UPDATE	JJP	7/29/93		

REVISIONS

EXHIBIT P



	NAME	TRANSFORMERS				
		NO. OF	KVA	VOLTAGE	COMPANY NO.	CIRCUIT NO.
A	INTOWN GARAGE	1	75	4160/277/480		2
B	SURFSIDE POOL	3	37.5	4160/120/208		37
C	PEOPLES BANK	1	75			2
D	FITCHBURG NEWS	1	150	208/120		2
E	THE MART	1	112.5	208/120		2
F	CHARLETON FURN.	3	50	4160/120/208	1290,1220,1225	4

THREE PHASE
ø A
ø B
ø C
DENOTES NUMBER OF CUSTOMERS ON A FUSE

REVISIONS

DRAWN MLC
CHECKED MAF
APPROVED

Unitil
Fitchburg Gas and Electric Light Company

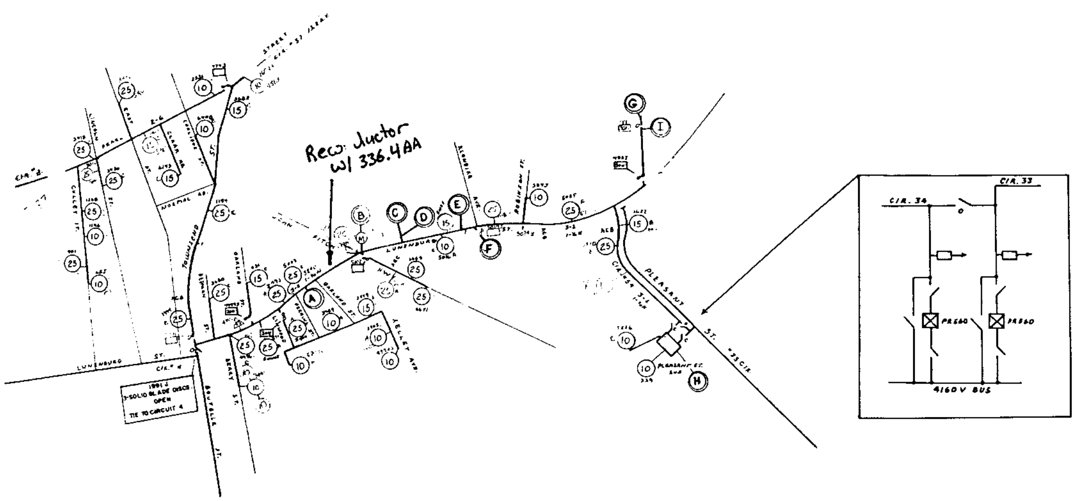
CIRCUIT DIAGRAM #37, #2
FITCHBURG MA

SCALE	DATE	SHEET	DRAWING NO.
1" = 200'	2/12/86	1 of 1	FDC37C

EXHIBIT Q


CIRCUIT DIAGRAM #4
FDC04
Unitil
Fitchburg Gas and Electric Light Company
SCALE 1" = 200'
DATE 11/4/98
SHEET 1 of 1
THREE PHASE
ø A
ø B
ø C
NAME
A SUMMER ST OFFICE BUILDING
B CHARLTON FURN.
TRANSFORMERS
1 300 4160/120/208 4330 PAD 4
3 50 4160/120/208 1290,1220,1225 4
4160 VOLT BUS (OUTDOOR)
AM 150 1200A
400A
TRANSFER BUS
CIRCUIT 4
REVISIONS
ELECTRIC STATION #2
NASHUA RIVER
SUMMER STREET
BOUTELLE STREET
ST. BERNARDS STREET
HARVARD STREET
GOODRICH STREET
HARRISON AVENUE
LAWRENCE STREET
BEACON STREET
WINTER STREET
BLUFF ST
MAVERICK
MARGERIE STREET
BOYLSTON STREET
FIFTH STREET
FULTON STREET
DANE STREET
SMITH STREET
GALE STREET
HANCOCK STREET
MATTHEW STREET
MILTON STREET
JOSLIN PLACE
HOLT STREET
OAK STREET
SAWYER PASSWAY
PRESCOTT STREET
LUNENBURG STREET
LINCOLN STREET
EAST STREET
TOWNSEND STREET
BERRY STREET
BERRY STREET EXT.
JERRY STREET
HARDY PASSWAY
JACKSON AVENUE
PITTS ST
UPHAM STREET

EXHIBIT R



REF. No	NAME	TRANSFORMERS No.	KVA	VOLTAGE	Co. No.
A	Speedway & Dunkin Donuts	3	25	208/120	2718 2719 2759
B	Beakey Photo	1 2	150 112.5	120/208	CUST. OWNED (IN VAULT)
C	Bennett	6	25	120/240	2976, 2977 2978, 2979 4960, 2531
D	Star Cleaners	3	50	120/240	1905 1906
E	Red & White	2	50	600	1405 1406
F	Thunderbird	1	225	4.16 - 13.8 120/208	Pad Cust. Owned
G	Hub Bowling	3	25	120/240	2517 2518 2520
H	Propane Plant	3	50	277/480	4358 4359 4360
	" "	3	100	120/208	2404 2405 2406
I	[illegible]	3	[illegible]	120/208	[illegible]

FDC34

FITCHBURG GAS and ELECTRIC LIGHT CO. FITCHBURG, MASS.

CIRCUIT DIAGRAM
34
3Ø 4160 VOLTS

DRAWN	KEL
DATE	1-18-83
SCALE	1" = 400'
	F-

EXHIBIT S

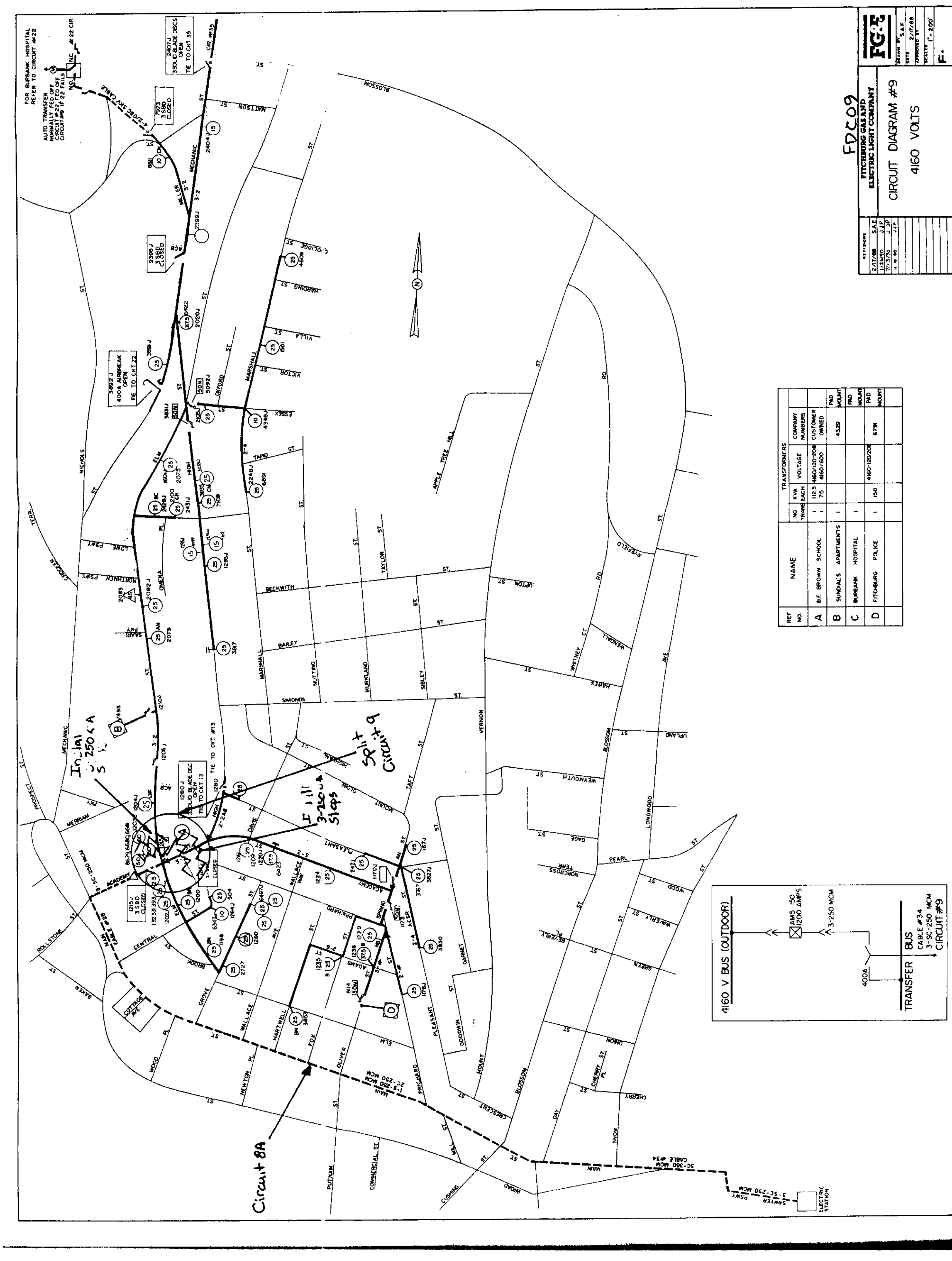

FD209
FITCHBURG GAS AND ELECTRIC LIGHT COMPANY
CIRCUIT DIAGRAM #9
4160 VOLTS
REF NO.
NAME
TRANSFORMERS
A B.F. BROWN SCHOOL
B SUNDIAL'S APARTMENTS
C BURBANK HOSPITAL
D FITCHBURG POLICE
4160 V BUS (OUTDOOR)
TRANSFER BUS
CABLE #34
3-SC 250 MCM
CIRCUIT #9
ELECTRIC STATION
FOR BURBANK HOSPITAL REFER TO CIRCUIT #22
Split Circuit 9
Circuit 8A

EXHIBIT T

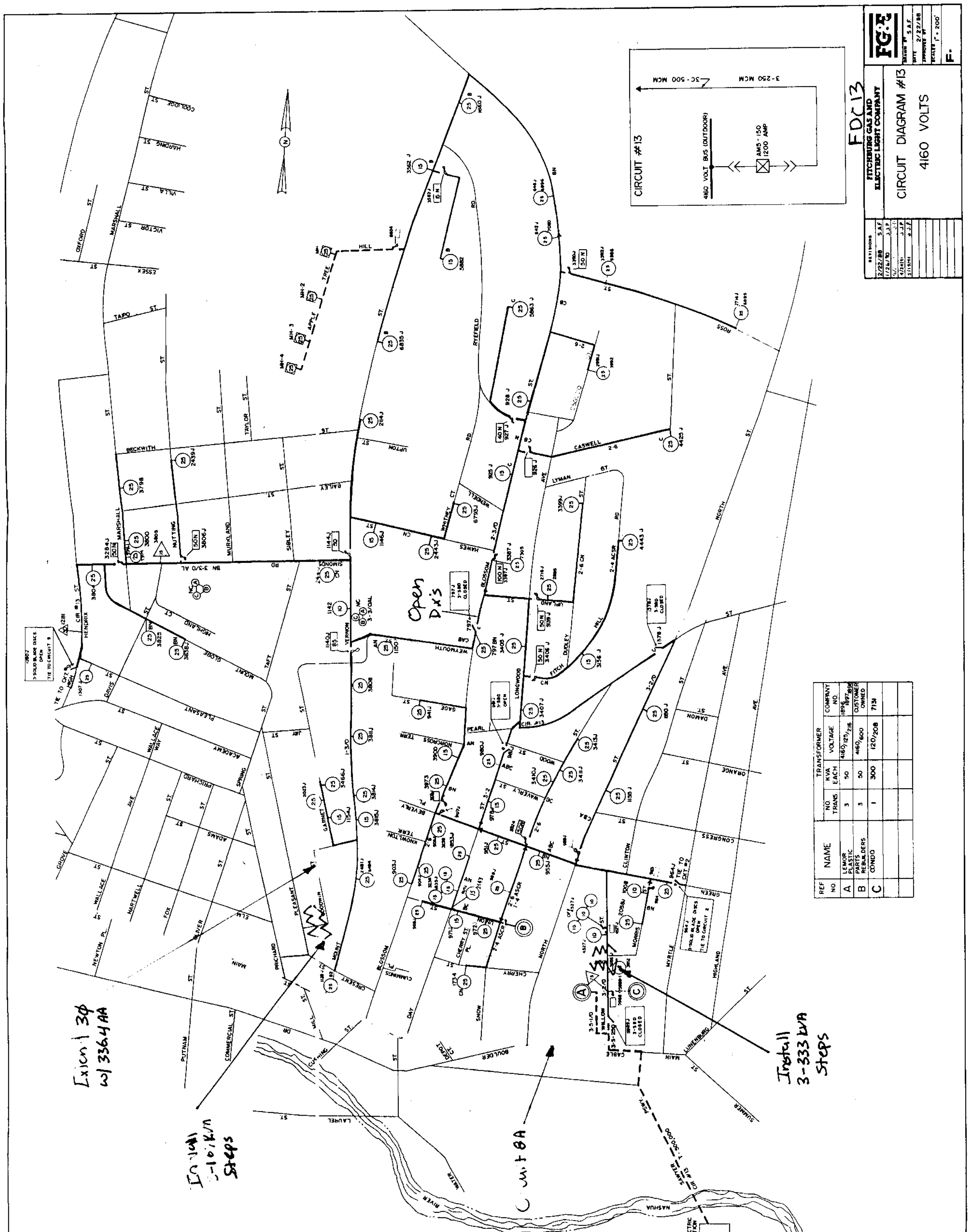

FITCHBURG GAS AND ELECTRIC LIGHT COMPANY
CIRCUIT DIAGRAM #13
4160 VOLTS
FDC13
CIRCUIT #13
4160 VOLT BUS (OUTDOOR)
Open D's
Install 3-333 kVA Steps
Extend 3Ø w/ 336.4 AA

EXHIBIT U

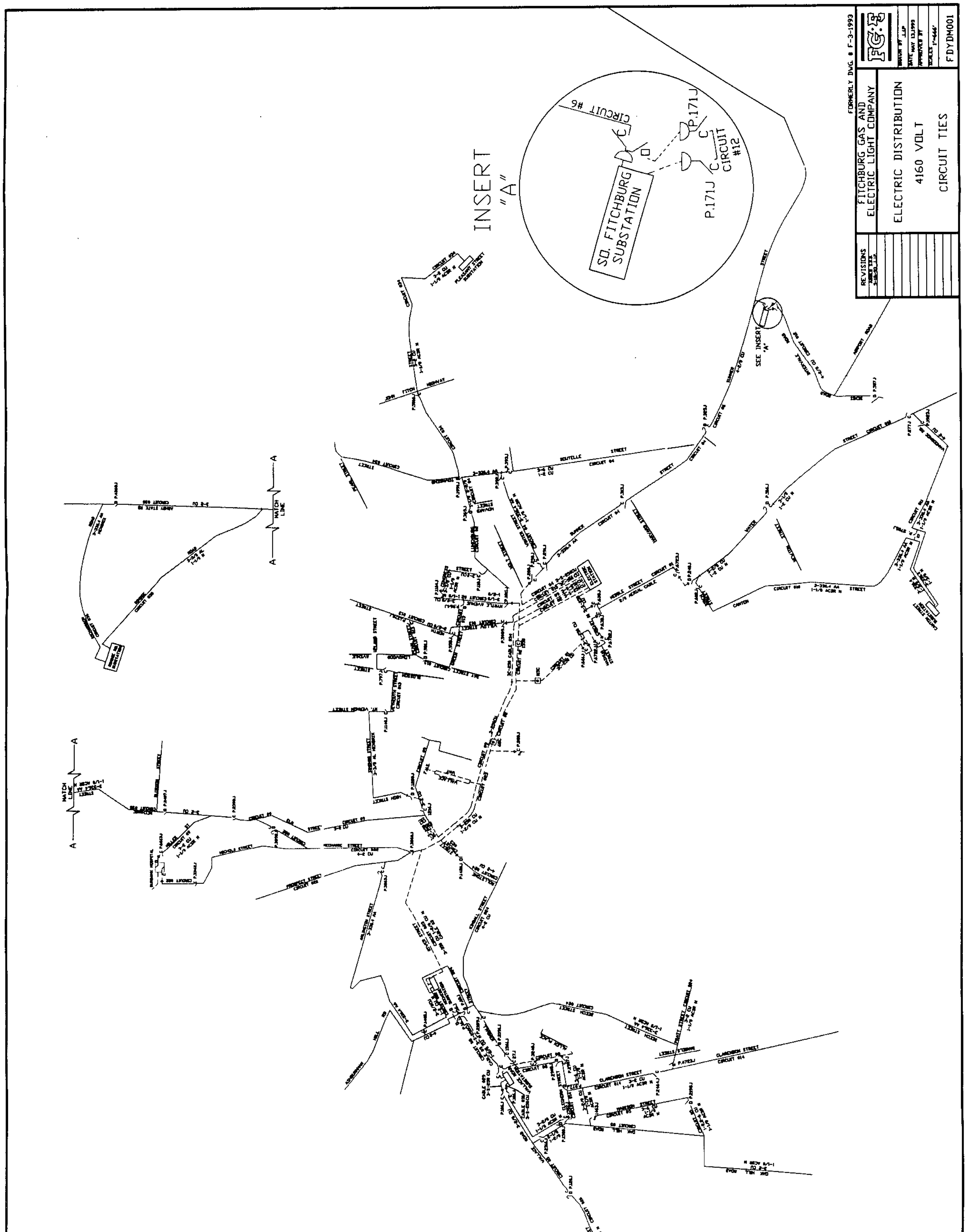
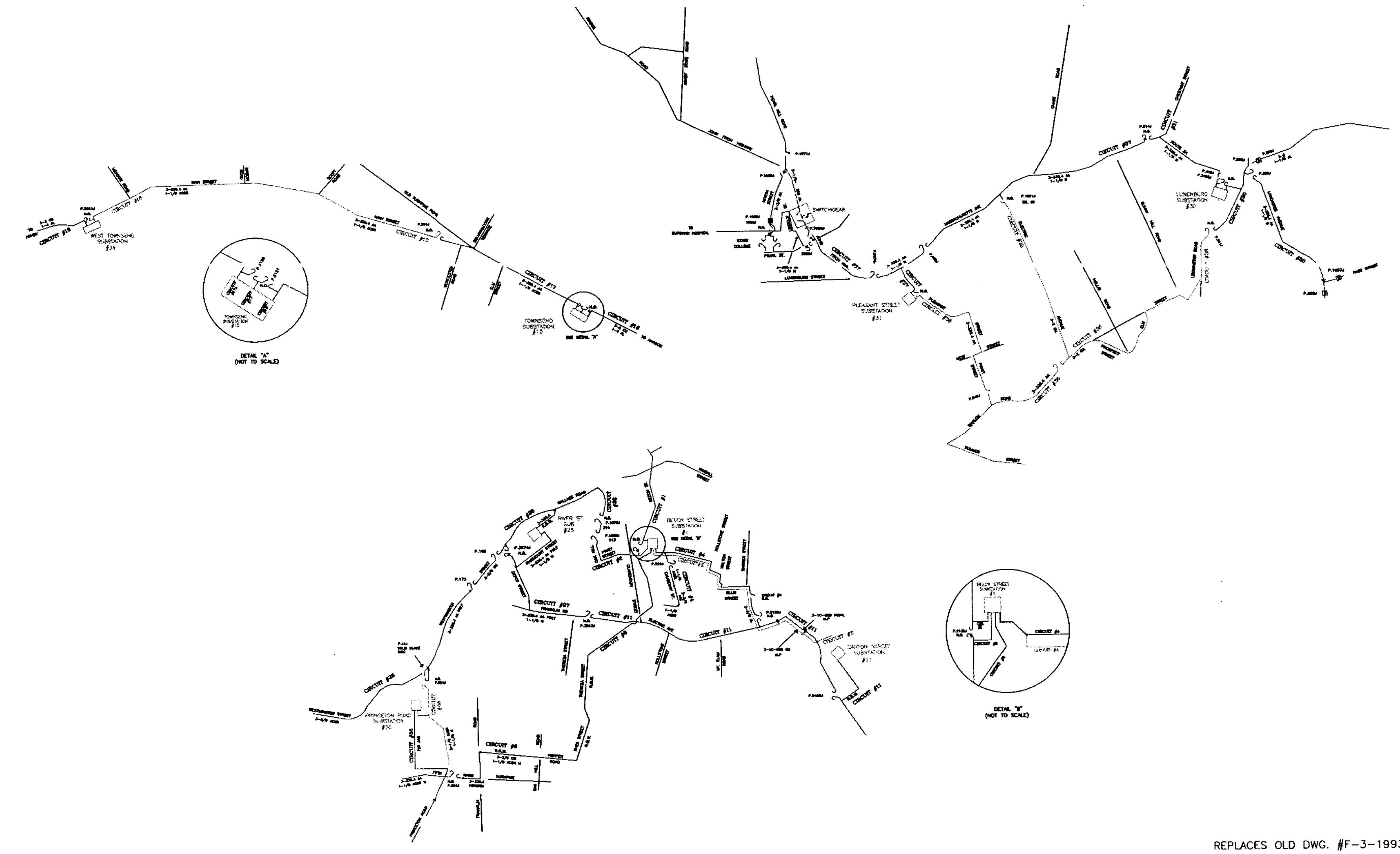

FORMERLY DWG # F-3-1993
FITCHBURG GAS AND ELECTRIC LIGHT COMPANY
ELECTRIC DISTRIBUTION
4160 VOLT
CIRCUIT TIES
FDYDM001
REVISIONS
INSERT "A"
SO. FITCHBURG SUBSTATION
CIRCUIT #6
P.171J
P.171J
CIRCUIT #12
SEE INSERT "A"
MATCH LINE
MATCH LINE

EXHIBIT V



REPLACES OLD DWG. #F-3-1993A

DRAWN	EMS
CHECKED	MAF
APPROVED	CEC

Unitil

Fitchburg Gas and Electric Light Company

ELECTRIC DISTRIBUTION
13.8 kV
CIRCUIT TIES

SCALE	DATE	SHEET	DRAWING NO.
1" = 1500'	4/20/93	1 OF 1	FDYDM002

REVISIONS